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Semi-Annual Status Report

Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana

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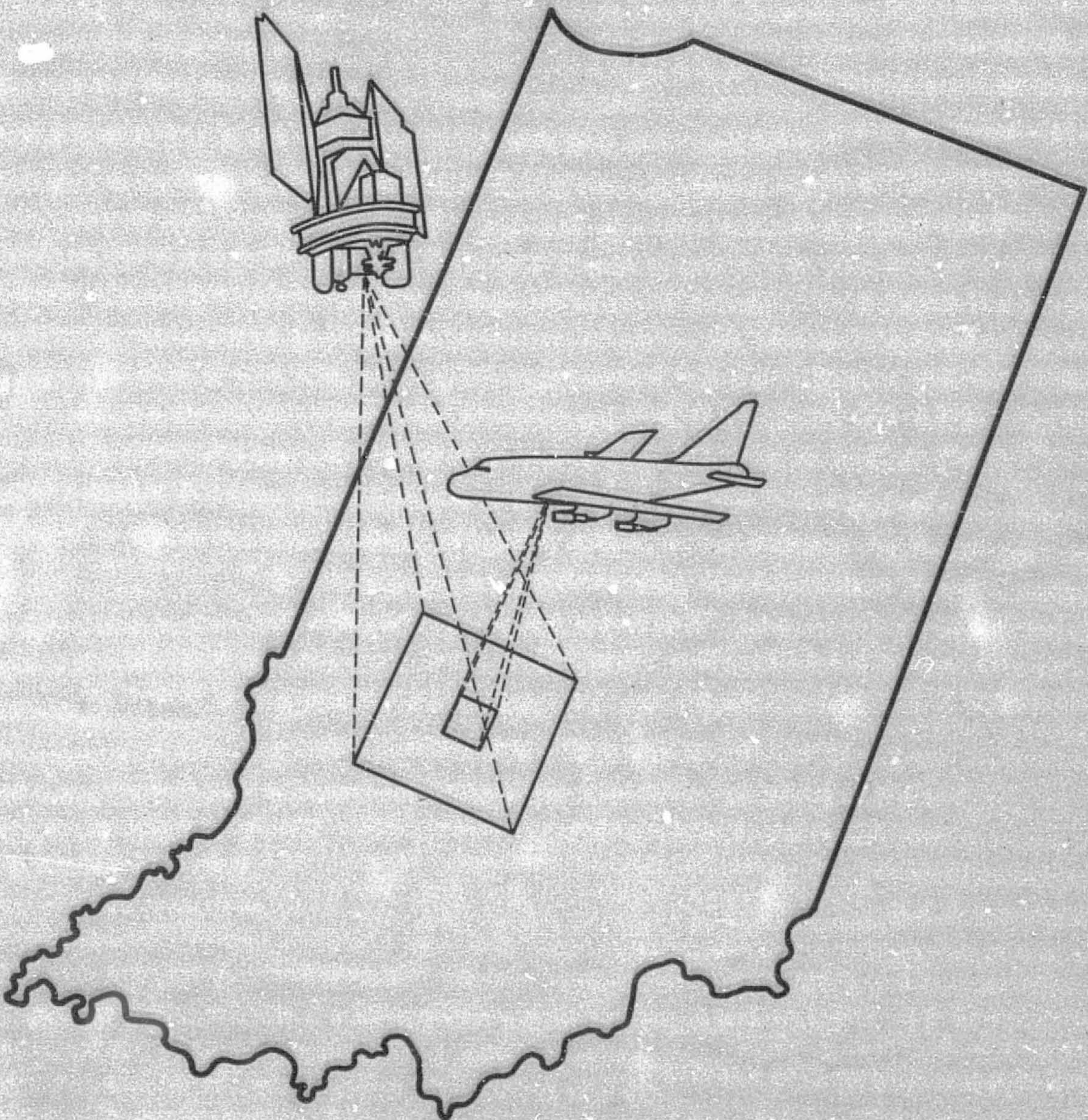

Laboratory for Applications of Remote Sensing
Purdue University W. Lafayette, Indiana
1977

SEMI-ANNUAL REPORT

Reporting Period: June 1, 1976 - November 30, 1976

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Title of Investigation:

The Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana

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INTRODUCTION

This semi-annual status report covers the period from June 1, 1976 to November 30, 1976 and contains a review of the research and applications, completed or in progress, as funded by the Office of University Affairs, NASA and conducted by Purdue University, Laboratory for Applications of Remote Sensing.

This reporting period marks the first half of the fourth year of funding for a proposal entitled "The Applications of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana." As indicated in this title, the purpose of this work is to introduce remote sensing into the user community within the state of Indiana. The user community includes those local, regional and state agencies involved in the decision monitoring and/or managing processes of the state's resources.

In order to carry out this work it is not only necessary to initiate projects with these agencies but also it is necessary to meet with and provide information to as many people and groups as well as agencies as possible. During the past six months numerous meetings were held with many different groups.

Among the groups that were contacted and received information about this program were:

Area Planning Commission, Boone County
Indiana Heartland Coordinating Commission
Indiana Geological Survey
U. S. Forest Service
Yorktown, Indiana Town Board
Yorktown, Indiana Plan Commission
Yorktown, Indiana Board of Zoning
Delaware County - Muncie Metropolitan Department of Planning and Zoning
Tipton County Commissioners and Engineers
Indiana Department of Natural Resources
  a) Division of Reclamation
  b) Division of Forestry
  c) Division of Properties, Fish and Wildlife
  d) Soil and Water Conservation Committee
Soil Conservation Service
St. Joseph County Area Plan Commission
Michiana Council of Governments.

Listed below are the projects that are reported in this document:

Data Base Applications
Power Plant Thermal Discharge
Surface Geology and Natural Resources Inventory
Soils Inventory
Forest Tent Caterpillar Inventory
Wetlands Mapping
Forestry Demonstration Project
Coastal Zone Management.

DATA BASE APPLICATION PROJECTS

BACKGROUND

The idea basic to this project is that the usefulness of land use classifications from satellite data will be enhanced if ancillary data pertinent to the user's task is available in registration with the remote sensing derived data. Three applications sites are being studied with ground derived and Landsat satellite derived data being combined in digital registration. All variables can then be processed by a computer program which can relate the variables and produce maps containing information of specific interest to planners or regulating organizations. The project began in 1974, with work on modification of an existing software for combining and processing a multivariate file of land use and physical data in a spatial array. Applications of these capabilities to three sites has progressed over the past year and these are discussed separately.

YORKTOWN, INDIANA SITE

Status

A detailed description of the physical data collected and inserted in the Yorktown data set was presented in the May 1976 six-month progress report. At that time there were thirteen variables in the system, all having to do with surface and sub-surface properties.

Since that date, two additional variables have been processed: zoning and land use. Zoning was extracted from zoning maps and manually coded into the ½ acre grid cells for the data set. This data was overlaid on the existing thirteen variables. Land use was obtained from two sources for comparison. Aerial photography was visually interpreted and a land use assignment made for each cell in the grid. This was inserted in the data set as Channel 15.

Landsat-2 multispectral scanner data was also processed to obtain an estimate of land use for each cell. Data from a May 1975 overpass was geometrically corrected and the Yorktown area was extracted. The data was clustered and training fields were picked using maps and previous knowledge about the spectral characteristics of such a scene in May. The area was classified using the LARSYS system and the results overlaid on the data file. This formed Channel 16 and this completed the data for the Yorktown site. The 1.3 acre pixels for Landsat were assigned to the ½ acre grid cells by the nearest neighbor rule which resulted in a duplication factor of about 2.6 for each pixel. The completed sixteen channel data set is available for combination processing for production of maps showing suitability or desirability for a particular use, or any assigned characteristic for a particular combination of variables.

The completed data file will be made available to the Yorktown Planning Commission through Dr. Hal Roepke and the Ball State University Computing Center. Intial products from the project were of sufficient interest to the Yorktown people to warrant continuation of the project under Ball State sponsorship. The software and data files are expected to be delivered to Dr. Roepke by the end of December 1976, at which time support of this project will end.

INDIANA HEARTLANDS SITE

Status

Early in the project it was proposed that a data file of several physical variables plus Landsat derived land use data for the eight-county Heartlands area be generated. The resources required to do this were found to be outside the scope of the project. At the same time the Holcomb Research Institute at Butler University assembled a data file adequate for the needs of the Heartlands; however, current land use was difficult to obtain. An evaluation was thus begun of land use classifications done earlier at LARS for the Heartlands area. An aggregation program was written which determined the majority class for cells containing a number of Landsat pixels. For the Holcomb data base the grid cells are 500 meters square and contain approximately 62 acres. The Landsat pixels are 57 by 79 meters in size. Blocks of approximately 9 by 6 pixels (54 pixels) are aggregated.

A test aggregation was generated for an area centered on Lebanon, Indiana, in Boone County in the Heartlands area. Aerial photography obtained on 70mm color film by LARS will be used to evaluate the accuracy of the aggregated classification. These results, along with a tabulation of the available classifications, will be presented to the Heartlands Commission for their consideration. Should aggregated land use classification data be requested, arrangements will be negotiated for delivering this data outside the scope of this program.

A complete description of the multivariable registration activity for Yorktown and the Heartlands, and the applications of this approach, will be assembled in a report to be produced after completion of the project on December 31, 1976. The Boone County work described below will be reported separately.

BOONE COUNTY, INDIANA SITE

Status

The purpose of this study is to develop a data base for a county-size area which can be used to meet the needs of planners and resource managers from local (town) to area (county) level. Information included in this data base involves physical characteristics of the surface and near sub-surface materials plus spectral response values based on Landsat imagery. Generation of the data base will be completed by the end of December 1976. Interaction with the data base to develop decision making procedures for town and county level planning will follow, but this work will be accomplished outside the scope of this project.

The so-called "environmental geology" data base will contain information on the following variables: 1) topography, 2) soils, 3) geologic materials, 4) geohydrologic character, 5) geologic hazards, 6) transportation systems, 7) urban centers and 8) surface cover materials (soil, vegetation, existing land use), this last group based on Landsat classifications.

The size of the grid or the cell size plays a significant role in this study. Gridded cells range in size from 1,000m^2 or 250 acres (LUNR, 1972) to 5m^2 0.5 acres (Roepke, 1975). The choice of cell size is governed, to a

large extent, by the scope of planning and the amount of time and funding available. However, if the data base is to be applied to local level planning, considerable detail is needed. Cell size selection is critical since too large a cell yields loss of needed detail and one too small dictates an overly time consuming and expensive endeavor. The study will compare the details and quality of several models using cells of different size, e.g., 500 ft. x 500 ft., 250 ft. x 250 ft. and 100 ft. x 100 ft. A determination will be made concerning which size is most suitable for depicting physical aspects of the land surface for town/county planning purposes.

The study area is situated in the south-east portion of Boone County, Indiana and includes the two largest urban centers, Zionsville (rapidly growing) and Lebanon (county seat). The area covers 190 square miles (487 km^2), which is approximately 45% of the county.

In view of the large size of the study area it is not practical to digitize all the data for the three cell sizes as this would involve 21, 221; 84, 885; and 530, 528 cells for the three grid sizes of 500 ft., 250 ft., and 100 ft. square, respectively. However, applying statistical sampling techniques, only a reduced percentage of the study area need be digitized for the smaller two grid cells with only the largest cell used throughout the total area. A resulting comparison will indicate the optimum cell size for the needed detail of local planning.

It is planned that special criteria will be developed to allow the computer to determine alternative uses of the land which are in keeping with environmental constraints. The inherent capabilities and constraints of an environmental resource for a given area dictates, to a large extent, its best land use. The computer data base can analyze each parcel of land 1) in terms of its physical characteristics (based on physical data and Landsat classification) and 2) according to decision-making criteria and then output the resulting capability models in map format. As an example, possible input factors for selecting a solid waste disposal site might be slope (calculated from elevations), soil group, depth to bedrock, type of bedrock, depth to first clay, depth to watertable, ease of excavation, availability of cover material, haul distance, existing zoning, agricultural value and vegetative cover. Some of these factors would be obtained from the Landsat classification.

Boone County has had a strong agricultural base but in recent years some of its prime agricultural land has been converted to urban areas spreading outward from Indianapolis. This has brought to focus the need for developing a long-range, comprehensive land use plan for the county. It is felt that this research will not only satisfy the needs of planners in Boone County but the results will apply equally well to similar counties in the Midwest region and particularly to those situated on the Tipton Till Plain Physiographic Province of the United States.

POWER PLANT THERMAL DISCHARGE PROJECT

INTRODUCTION

In previous work in this area, a three-dimensional mathematical model which describes the distribution of heat in a flowing or non-flowing body of water has been developed. This model (THRM3D5) uses the surface water temperature measured through remote sensing as the boundary condition in conjunction with the velocity field of the main body of water, and the velocity field for the impinging stream which is carrying the heat, to calculate the below surface temperature profile.

PROGRESS

Due to reduced effort of staff on this project, little progress has been made. The THRM3D5 code has been modified to decrease its required computation time and it is now considered as an operational program. Also a LARS owned Fast Scan Thermal Infrared Camera has been brought into an operational mode and is available for collection of thermal imagery. Two major advantages of the camera system as it is configured for the project are:

1) reduced cost of remote data collection (The system is portable and readily attached in a helicopter.)
2) allows for the collection of real time imagery (One can hover over a site, view the data being collected on a cathode ray tube, and then record on tape the desired data frame.)

This system will be tested in early spring. Data will be collected at the City Water, Light and Power Company Plant of Springfield, Illinois. Results generated from the tests will be used by the city to help with making environmental decisions (e.g., a 316(a) demonstration study) in relation to Region 5 of the US/EPA.

The reduced cost of data collection (made possible with the thermal camera system) is very important since this is one of the major impediments for operationally using the techniques developed under this project. Costs associated with the Springfield study will be quantified and a comparison will be made with a similar investigation not using remote sensing techniques.

SURFACE GEOLOGY A'D NATURAL RESOURCES INVENTORY PROJECT

INTRODUCTION

The following report discusses the use of computer-assisted classifications of Landsat MSS imagery in supplying needed informa '-- (surface materials, including vegetation) for drafting a new zoning ordinance and attendant zoning maps for St. Joseph County, Indiana. This effort was initiated at the request of the Director of the St. Joseph County Area Plan Commission, Mr. Richard Johnson. This Commission has jurisdiction over the entire county including the city of South Bend, and has long been a recognized progressive leader in area planning for housing development and zoning.

Regional land use studies today are accomplished in large measure by standard photointerpretive techniques. These are time consuming and if larger areas such as counties and region planning districts are to be studied in sufficient detail, more efficient procedures will be needed. Photointerpretation is also limited by the skill of the individual and seriously curtailed by the shortage of qualified individuals in local planning agencies. This second aspect is borne out by the recent request for proposal by the Federal Highway Administration to develop a workshop on photointerpretation and remote sensing for state highway agencies (FHWA, 1976). It has been demonstrated that computer processing techniques for analyzing multispectral scanner data for land use can be used with greater speed and accuracy as compared to that of manual methods (Melhorn, et al., 1973; Todd and Baumgardner, 1973; and Mausel, 1973).

DESCRIPTION OF STUDY AREA

St. Joseph County is located in north central Indiana (Figure 1) in the high population section of the state along the northern tier of counties adjacent to Chicago, Illinois and directly south of Michigan. The county contains a contrasting variety of glacial landforms including till plains, outwash plains, lake deposits and a vast quantity of organic materials. Urbanization to date has developed in accordance with these geologic conditions (some deposits yield significant foundation problems for houses and other buildings) and with the general location of adjacent population centers, (Mishawaka, Elkhart, and Goshen, Indiana; Niles, Michigan). The Area Plan Commission plans to direct this development in the county in accordance with zoning based on these physical and political factors.

Principal land uses in the county are agricultural and urban with the city of South Bend occupying the central portion of the county. The soils tend to reflect the drainage conditions and texturally they range from fine sands to organic deposits.

ANALYSIS PROCEDURE

A preliminary study was undertaken on a section of the county at the outset of the project using in-house Landsat imagery from 1973. Based on the results of this preliminary work, the St. Joseph County Plan Commission urged that the study be performed on the entire county using more recent data to

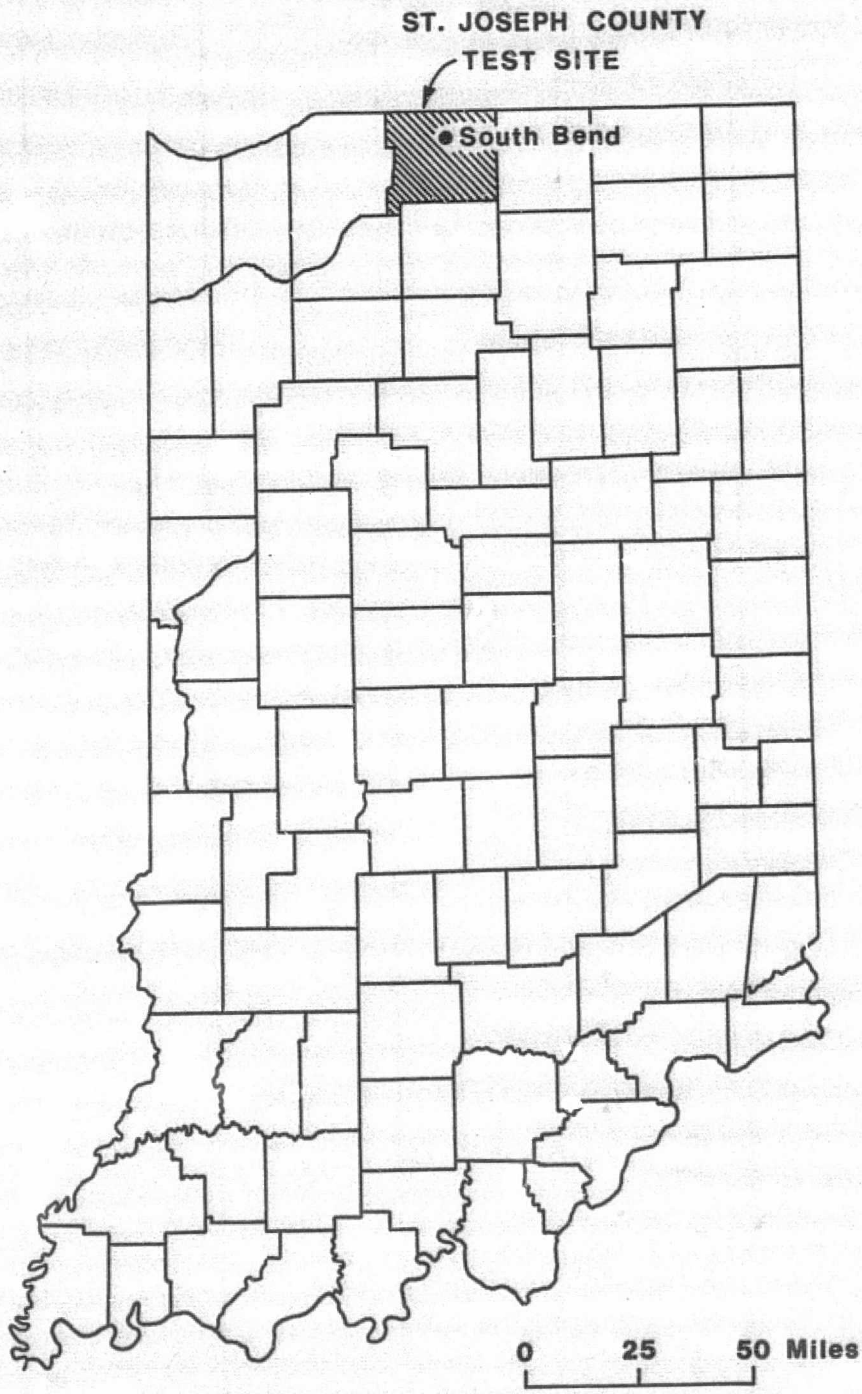

Figure 1. Site Location for Surface Geology and Natural Resources Study.

determine current land use as well as the cover type information.

A study of the Lydich USGS $7\frac{1}{2}''$ Quadrangle in the northwestern portion of the county was accomplished using June 8, 1975 data.

OBJECTIVES OF ANALYSIS

The objectives of the analysis were: 1) to use computer-aided analysis of Landsat data to obtain a land use and cover type classification of the Lydich Quadrangle and 2) present output in a form most useful to the user.

DATA ANALYSIS

Four areas, 40 lines by 40 columns, were selected which contained representatives of each cover type within the quadrangle. The areas were clustered resulting in fifteen spectral classes of material. Ratioing of the spectral responses in the visible versus the reflective infrared was performed on all the classes to aid in delineating what each class represented. Definable areas on the cluster maps were compared to aerial photographs of 1973. In this manner, the classes delineated by spectral response through the clustering algorithm were defined. Statistics on each subset of classes were calculated. Spectral classes which were not significantly different were combined and their statistics merged through the MERGESTATISTICS function of the LARS software system. Subsequently, the SEPARABILITY program was used to determine the separability of the newly merged classes. Similar classes were once again combined and their statistics merged resulting in a final set of statistics which was used in the classification process.

RESULTS

The Lydich Quadrangle area was successfully classified into seven cover types: 1) trees, 2) poorly drained soil and water, 3) pasture land, 4) well drained brown soil, 5) moderately well drained dark brown soil, 6) moderately drained soil, and 7) medium to poorly drained soil. Figure 2 is a photo reduction of the line printer classification of the site and the symbols *,W, +, ,0,=, and · represent classes 1 through 7, respectively. The organic soil areas were delineated particularly well. These areas are of great importance to the Area Plan Commission because of their desire to use the results as a basis for a new zoning plan.

DISCUSSION

The Landsat classification is more beneficial than the existing agricultural soils maps because it shows the current ground cover of trees as well as pasture land which is significant for the decision making process. Although the Level II classification in USGS Circular 671 (Anderson, et al., 1972) groups cropland and pasture into one category, it was not done in this study because more information of a useful nature to the user is obtained by using the two classes. It is a combination of the necessary detail of cover type, the useful scale of presentation and current nature of the classification and ability to update it readily that makes this work so valuable to this planning agency.

GEOL77 JORDAN

LABORATORY FOR APPLICATIONS OF REMOTE SENSING
PURDUE UNIVERSITY

NOV 10,1976
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LARSYS VERSION 3

CLASSIFICATION STUDY 631547833	CLASSIFIED NOV 10,1976
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FLIGHT LINE... 213715472 IN	TIME DATA TAKEN..... 0947 HOURS
DATA TAPE/FILE NUMBER.. 3485/ 1	PLATFORM ALTITUDE..3062000 FEET
REFORMATTING DATE, OCT 16,1976	GROUND HEADING..... 180 DEGREES

CLASSIFICATION WRITTEN ON DISK

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
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LABORATORY FOR APPLICATIONS OF REMOTE SENSING
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CLASSES

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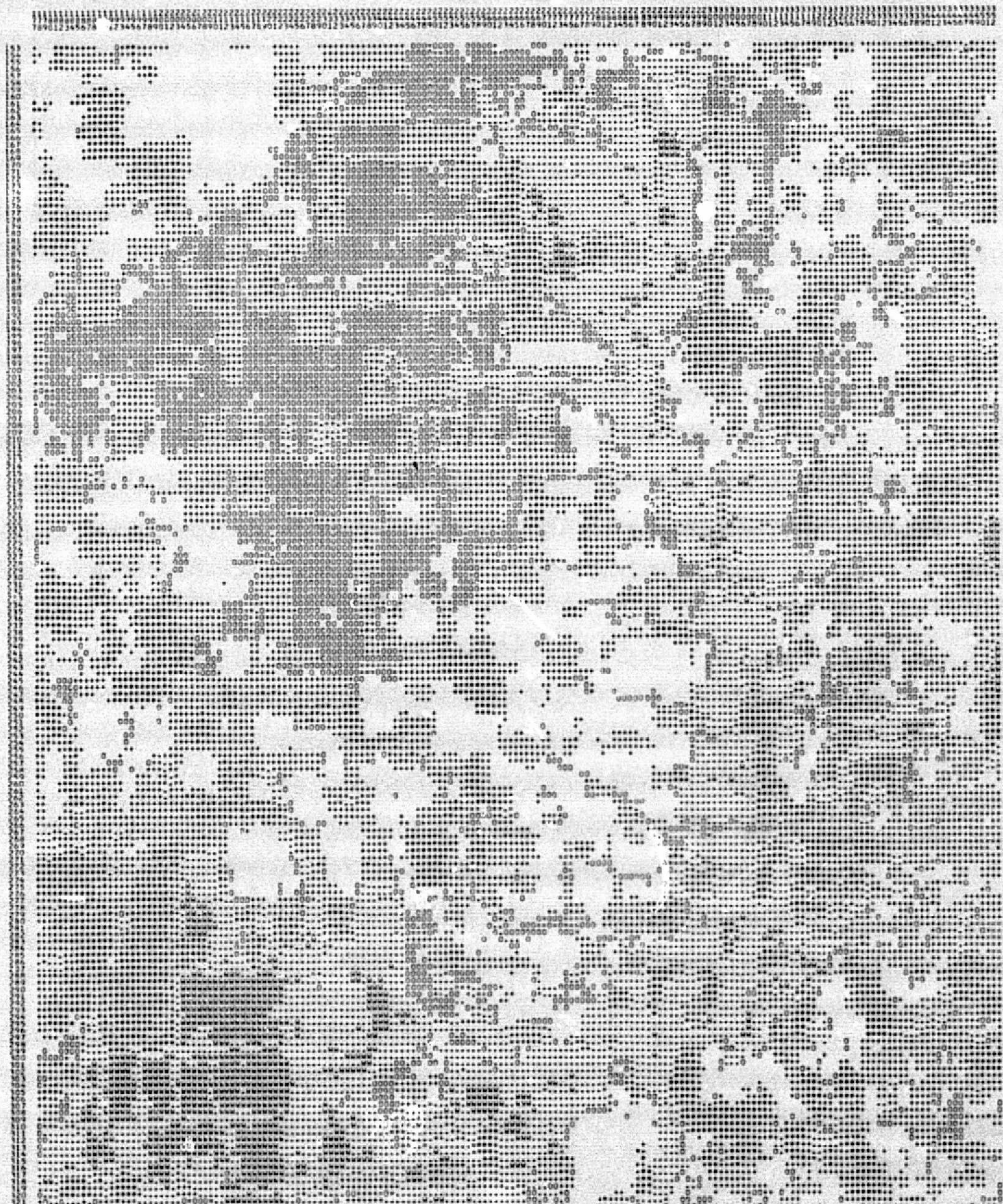

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8.876 SECONDS. (LARSMN)

Figure 2. Classification of Surface Materials, Lydich Quadrangle, St. Joseph County, Indiana.

The St. Joseph County Area Planning Agency has been pleased with the amount and quality of information which can be generated from computer-aided analysis of Landsat data. They have indicated a continual commitment to use the information as soon as it is available for the entire county.

In addition, the Michiana Council of Governments (MACOG) which has its central office in South Bend, Indiana is greatly interested in the prelimanary results and have indicated that they would consider using this method to monitor land use changes in the four northern Indiana counties (plus others in Michigan). It is the present plan to use the St. Joseph County classification as a demonstration package for MACOG to determine their interest in funding similar studies in the remaining counties.

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SOIL INVENTORY PROJECT

INTRODUCTION

The acceleration of the National Soil Survey Program and the production of useful, high quality soil surveys in Indiana are among the prime goals of the USDA/Soil Conservation Service and the Indiana Department of Natural Resources Soil and Water Conservation Committee. The wide use of soil surveys for engineering and planning purposes in addition to agricultural uses has resulted in many specific questions concerning the physical nature of the different soil units depicted on soil maps. In order to provide the details necessary to understand the landscape composition and to provide interpretation of soil maps for specific uses, information of a quantitative nature is needed. To accomplish this task all avenues are being considered, including remote sensing technology which can provide quantitative measurements through computer analysis of Landsat multispectral scanner (MSS) data.

OBJECTIVE

The overall objective of this task is to determine the applicability of using computer analysis of Landsat multispectral scanner data in accelerating and improving the quality of the soil survey program in Indiana.

Early in 1976 field evaluation of computer analyzed Landsat MSS data collected over Clinton and Jasper Counties indicated that remotely sensed data could be extremely useful in aiding the Indiana soil mapping program. To further evaluate the usefulness of the data the following specific studies were initiated:

1. Determine the feasibility of using spectral information to differentiate between alfisol and mollisol soils of the aquic suborder. These two soils have such a subtle difference in landscape and in surface color that it is impractical to separate them without extensive sampling.

2. Evaluate the usefulness of spectral soil maps produced from multispectral scanner data using pattern recognition techniques as a quality control in soil surveys and as a means to evaluate quantitatively the soil mapping unit composition.

3. Investigate the possibility of producing high quality general soil maps using false color Landsat imagery as the base map.

4. Develop a soil parent material map using multispectral resource data.

5. Determine the feasibility of producing a spectral soil map on a county-wide basis with its accompanying manuscript and evaluate the utility of this type of soil survey report to user groups.

6. Evaluate the usefulness of superimposing computer classification results upon aerial photobase maps in order to gain the benefit of the landscape perspective.

STATUS

During the field mapping phase of the Clinton County, Indiana soil survey, the soil scientists have had great difficulty in separating two very similar soils when they occur in close association of one another. These were the alfisol (Brookston series) and the mollisol (Drummer series). These soils occupy similar landscape positions, have similar surface and subsoil colors and have a somewhat similar clay content.

The State Soil Scientist of Indiana has determined a need for supplemental data to aid soil scientists in the field in separating these two soils, without relying upon extensive field sampling and laboratory analysis. The feasibility of using computer analyzed Landsat MSS data for the purpose is being pursued.

Two areas within Clinton County which had been mapped by conventional methods were chosen as the study sites. From one of these sites an area representative of the poorly drained alfisol (Brookston) was selected and from the other site an area representative of the poorly drained mollisol (Drummer) was selected. The corresponding areas of each of these soils were identified on the computer generated spectral maps and the spectral statistics for the data were calculated. The mean relative responses of the alfisol and mollisol soils in the four Landsat wavelength bands show that a significant spectral difference exists between these two soils (Figure 1). These statistics indicate that the two soils are spectrally separable. The statistics describing these spectral differences were used to classify the areas where the two soils coexist.

Thus, it appears that the soil scientist, equipped with a transparent computer generated soils map made to the same scale as the aerial photo field sheet, can use this aid in making the difficult separation between the Brookston and Drummer soil series.

In addition to delineating the boundaries of soil mapping units (an area of soil on a soil map which contains one or more taxonomic units plus some inclusions), the soil scientist should describe, quantitatively, each mapping unit. Commonly mapping units contain one predominating soil series and lesser inclusions or impurities of other series. The proportion of inclusions tends to increase as the intricacy of the soil pattern increases.

Maximum proportions of soils allowed as inclusions within a mapping unit may range from 15 to 50 percent, depending on the degree of contrast between included kinds of soils (similar inclusions) and the most extensive soil. Only 15 percent of contrasting inclusions are permitted. If two or more taxonomic units occur in more or less regular pattern and are so intricately mixed, or so small in size that it is not practical to separate them, a soil complex must be established. The percent of contrasting inclusions allowable in a complex is less that 25. When contrasting inclusions exceed 25 percent, the mapping unit must be identified as a undifferentiated group or soil association.

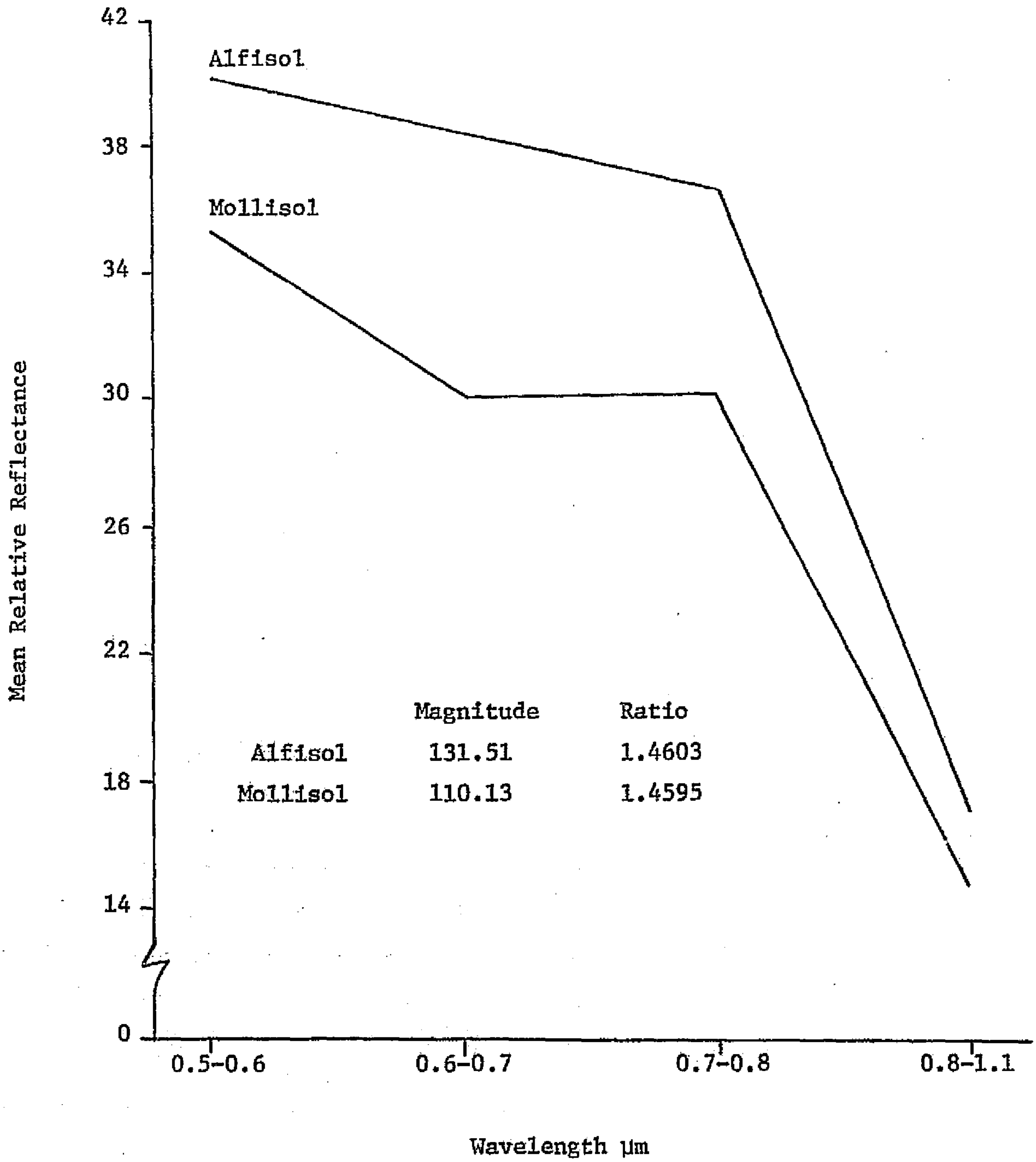


Figure 1. Spectral Response of Alfisol and Mollisol Soils.

Most soil scientists vary in their ability to execute a survey and therefore each individual may define the quantitative purity of a mapping unit differently. In order to define mapping units more accurately and uniform the soil scientist needs more quantitative data. Computer analyzed Landsat MSS data can be a very useful tool with which to greatly improve the quality and quanity of soil mapping.

In a paper entitled "Mapping Accuracy of Contemporary Soil Survey in Urbanizing Area" 1975 by Amos and Whiteside the following conclusion was reached:

> On the basis of this and other recent studies, the time seems most opportune to initiate a modernization and quantification of mapping unit definitions in contemporary soil survey reports. Assuming we are delineating complexes, we should so designate the mapping units and list the percentage of major components they contain. This should result in surveys more usable for interpretive purposes and surveys of more lasting value.

Attachment 1 explains how multispectral data can be used to evaluate the homogeneity of a mapping unit by determining the nature of the inclusions, and also their size and extent. The detail observed in Figure 1 of Attachment 1 is impossible to obtain while walking the land during conventional mapping. Therefore, multispectral data is a valuable tool with which to evaluate quantitatively, conventional soil mapping units.

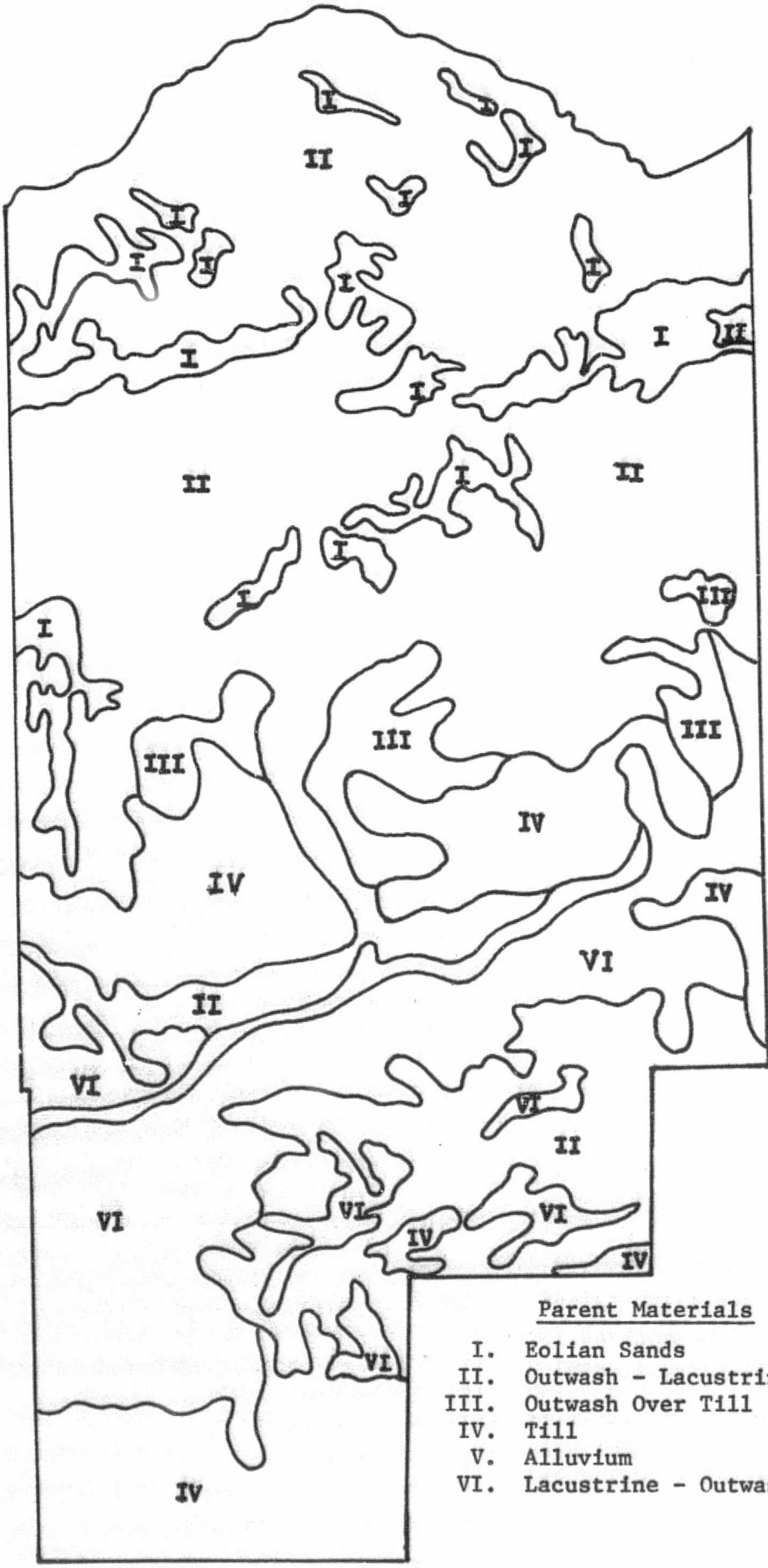
The extent of a soil within a soil complex is very difficult to determine. However, soil scientists should know, early in a survey, the percentage of each individual soil in order to identify and properly name any given complex. Using a technique similar to the one described in Attachment 1 (Figure 1 & Table 1), the relative percentage of individual soils within a mapping unit can readily be determined. This information can then be made available to the field personnel and used during the survey to improve their final product.

Another important criteria used to separate soils is the identification of the internal drainage of soils (i.e., well drained, moderately well, somewhat poorly, poorly drained, etc.). This information generally entails a considerable amount of field sampling to be identified and described. Current work indicates that remotely sensed data, when properly analyzed, can identify the moisture regimes of soils. Figure 1 of Attachment 1 shows the separation of the various inclusions in a mapping unit based upon internal drainage.

Also, as a part of the total soil survey a general soils map is prepared for each county. This map is a small scale map delineating the major soil associations within the county. Presently, the soil boundaries on the general soil map are located by interpreting the detailed soils map. Often, the placement of the soil boundaries can be difficult and sometimes arbitrary. In White County, Indiana false color Landsat imagery was used as a base map and generalized soil boundaries were delineated based upon visual interpretation of this data. Figure 1 of Attachment 2 is a copy of the generalized soil map developed from the false color imagery. A technical paper describing this method is included as Attachment 2.

Work is progressing on the generation of a spectral soils map of Jasper County, Indiana. The Soil Conservation Service (Indiana) has provided excellent reference material in the form of a set of high quality aerial photos of Jasper County at a scale of 1:15,840, dated May 1976. Present technology cannot accurately separate individual soil series using only computer-aided analysis of MSS data. However, one method of identifying individual series is being evaluated by the use of ancillary data to stratify the Landsat data based on soil parent material. Using this technique each area representative of a particular parent material can be classified independently and thus soil series can be more easily identified. This method will be used in Jasper County and a parent material map of Jasper County has been developed using visual interpretation of false color Landsat imagery (Figure 2). After the computer analysis is complete, the computer classification will be superimposed onto aerial photos. This will allow for the inclusion of the landscape perspective when interpreting the soil maps produced by spectral analysis. The spectral soil map generated will be accompanied with a complete soil manuscript and distributed as an interim soil survey of Jasper County. As people use this report, an evaluation of the utility of the spectral map will be conducted.

Also during this reporting period, the Indiana Department of Natural Resources, Division of Nature Preserves, requested assistance in mapping vegetative colonies on a relatively small tract of land (121 hectares) called the Hoosier Prairie. To date no attempt has been made to work with such a small tract of land. This project was completed and the results presented at a meeting of the Indiana Academy of Science. Attachment 3 presents this effort in more detail.



<u>Parent Materials</u>

I. Eolian Sands
II. Outwash - Lacustrine
III. Outwash Over Till
IV. Till
V. Alluvium
VI. Lacustrine - Outwash

Figure 2. Jasper County Parent Material Map.

ATTACHMENT 1

Mapping Unit Composition As Defined by Digital Analyses of Landsat Multispectral Data

Introduction

Soil mapping units, historically, have been the basis for predicting soil conditions at a particular site. "The fraction of the predictions which prove to be correct, wholly or within acceptable limits, measures the utility of the soils map."[1] In order to evaluate the composition of a mapping unit, it is necessary to know the kind and extent of the various components of the unit. Such techniques as line-intercept and point-intercept transects have long been used to estimate the composition of a soil mapping unit.[2] These methods do provide a means of determining the purity of a unit, however, the location and extent of the inclusions are difficult to ascertain, and this determination is largely one of empirical judgment.

This paper examines the composition of three distinctly different mapping units, based upon the multispectral reflectance of the components of each unit. Spectral data characterizes the drainage classes and furnishes a basis for determining the size of the units and also the size of each inclusion.

Method

A clustering algorithm was used to divide the multispectral scanner data into groups of data points having similar spectral characteristics. The relative spectral values and covariance matrices for each individual cluster were calculated. The resultant 15 clusters were then grouped, based on their statistical separability, into 5 distinct classes.

The magnitude of the reflectance and the ratio of the sum of the visible spectral reflectance values to the sum of the near infrared reflectance values were used to relate the 5 cluster classes to 4 soil drainage classes, and one vegetative class. A maximum likelihood algorithm was then used to classify each pixel in the 6½ square kilometer study area into one of the 5 classes.

An alphanumeric, 1:24,000 scale, map was prepared for the area and three contrasting soil mapping units (Figure 1) were selected for study. These units were the Mahalasville silty clay loam, the Reesville silt loam with 0 to 2 percent slopes and the Xenia silt loam with 2 to 6 percent slopes, eroded. The boundaries of these units were transferred from the field sheets on which they were originally mapped to the classification map. Sites were reviewed in the field and sufficient investigation was made to substantiate the existance of most of the inclusions identified. Each mapping unit was scanned and measured to determine the total size of the unit and the total number of hectares of each individual mapping inclusion.

Results

Measurements of the percent of the mapping unit represented by the named soil series range from 44 to 55 percent. If the class identified as vegetation is combined with the named unit the range increases from 54 to 64 percent. The Xenia mapping unit was the only unit represented by less than 50 percent of the named unit. The somewhat poorly drained inclusion in the Xenia unit accounted for 34 percent of this unit, poorly drained 9 percent and vegetation 13 percent. The Reesville unit was represented by 50 percent of the named unit, 17 percent by a moderately well drained inclusion, 18 percent by a poorly drained inclusion, 1 percent by very poorly drained and 14 percent by vegetation. If the vegetation class was added to the named unit, the percentage increased to 64 percent. Mahalasville is represented by 55 percent of the named unit and no vegetation is represented in this unit. 16 percent of the inclusions are somewhat poorly drained, 21 percent of the inclusions are very poorly drained and the moderately well drained inclusion makes up 8 percent of the mapping unit.

Discussion

Ever since the first soil survey was initiated, determining the nature and extent of mapping unit inclusions has been a difficult problem. This study points out that Landsat multispectral data can be used as a tool in making determinations about mapping unit inclusions that heretofore could only be made by very intensive field work.

In the Mahalasville mapping unit (Figure 1 & Table 1) multispectral data identifies a 10 hectare block of very poorly drained soil whcih could be mapped independent of Mahalasville. The data also indicates numerous small areas 1 to 3 hectares in size which cannot feasibly be separated on maps having a scale of 1:15:840 or smaller.

Multispectral data indicates that the Xenia mapping unit (Figure 1 & Table 1) has sufficient inclusions of other units to warrant adding another series name to the mapping unit or separating out another unit from it.

The complex delineation line of the Reesville mapping unit (Figure 1 & Table 1) indicates a rather intricate soil pattern, therefore, a high percentage of inclusions may be expected. Areas of poorly and moderately well drained inclusion are of sufficient size so that they could be mapped out independently.

A very practical application of a soils map derived from Landsat multispectral data is its potential use in training soil scientists on mapping techniques. Knowing where to make a soil boring in the landscape is a technique learned only after considerable field experience. The digital soils map can be useful in locating these soil boring sites. Another potential use could be for quality control purposes. The purity of a mapping unit may be ascertained without setting foot on the landscape. Soil complexes might also be evaluated and the naming of complexes could be better verified by referring to Landsat multispectral information.

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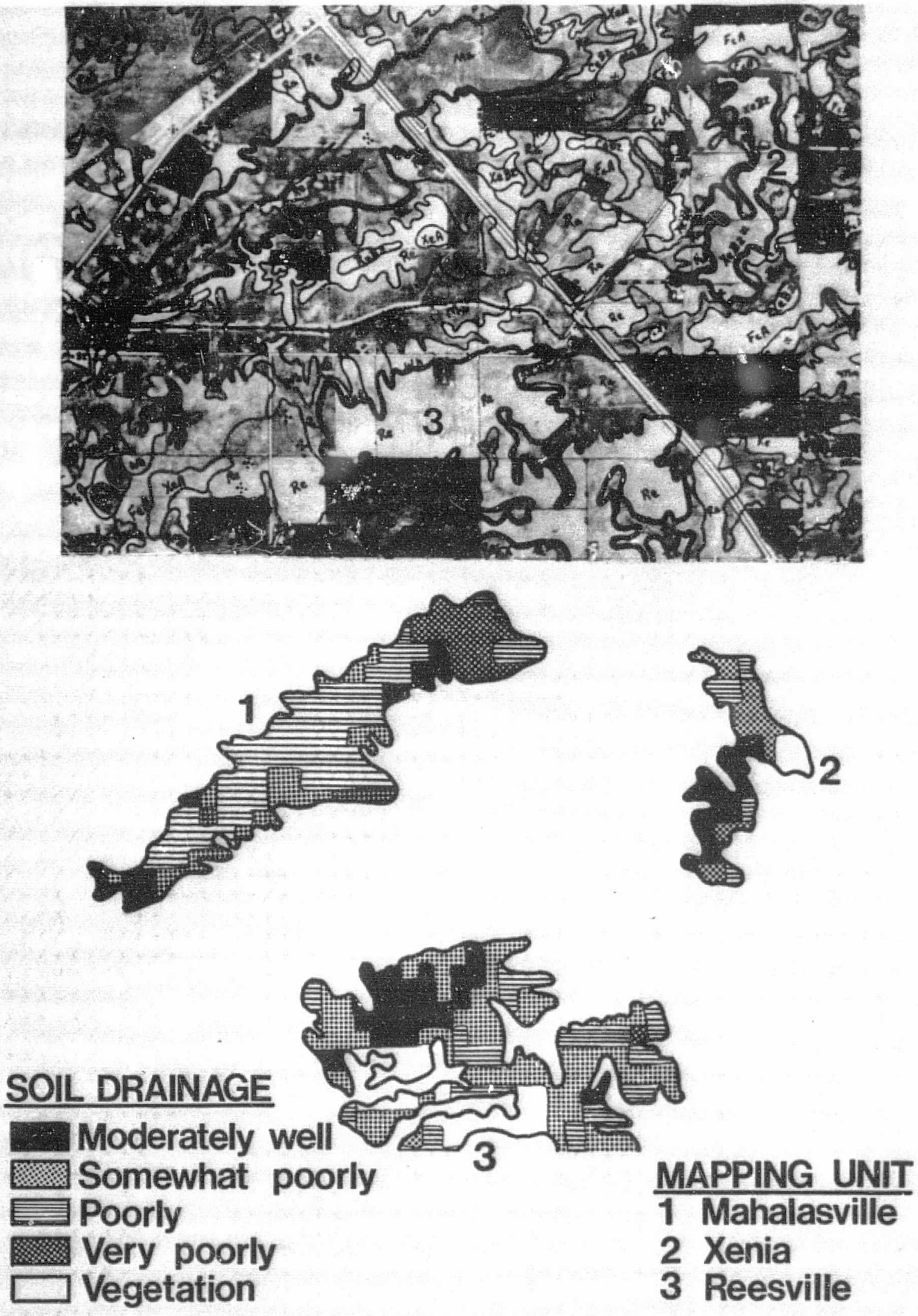

Figure 1. Composition of Soil Mapping Units.

Table 1. Composition of Soil Mapping Units.

Characteristics of Named Mapping Unit

Mapping Unit	Spectral Class	Internal Drainage Class	Size of Mapping Unit (Hectares)	Percent and Area (Hectares) of Mapping Unit
Mahalasville silty clay loam	X	Poorly	49.39	55% 31.09
Reesville silt loam, 0 to 2 percent slopes	+	Somewhat Poorly	62.75	50% 30.40
Xenia silt loam, 2 to 6 percent slopes, eroded	/	Moderately Well	14.97	44% 6.59

Percent and Area (Hectares) of Inclusions within the Above Mapping Units Identified by Drainage Classes

Spectral Symbol	Very Poorly Drained	Poorly Drained	Somewhat Poorly Drained	Moderately Well Drained	Vegetation
X	21% 10.24	--- ---	16% 7.91	8% 4.19	--- ---
+	1% 0.46	18% 11.17	--- ---	17% 10.24	14% 8.84
/	--- ---	9% 1.39	34% 5.12	--- ---	13% 1.86

ATTACHMENT 2

Use of Landsat Imagery as a Base Map for Making a General Soils Map

Introduction

A general soil map shows a grouping of similar soils called soil associations. A soil association represents a distinctive landscape unit with relatively definite proportions of soil series. General soil maps are an essential part of each published soil survey for they provide important resource data for a wide range of uses.

A county road map is often used as a base map for developing a general soil map. Soil associations are delineated onto the base map using data extracted from the detailed soil map. When soil associations gradually grade into each other, problems arise in trying to determine where the association boundaries are to be placed.

The purpose of this study was to determine how color Landsat information could be used for preparing a general soil map for White County, Indiana. Previously Steinhardt et al. (1974) compared existing general soil maps with black and white satellite imagery (2).

Materials and Methods

A geometrically corrected color composite multispectral image derived from June 3, 1973, Landsat data and scaled to approximately 1:125,000 was used as a base map for delineating soil association boundaries. Detailed soil mapping on aerial photographs at a scale of 1:20,000 was available for 75 percent of the county.

Locating oneself on Landsat imagery is often time consuming because certain areas lack easily identifiable reference points. To overcome this problem, county boundaries, major streams, towns, and the boundaries of the detailed soils maps were inked on frosted acetate which was placed on the Landsat imagery. The straight vertical and horizontal lines in Figure 1 are the soil map boundaries.

In White County the boundary between the sandy soils in the north and the loamy soils in the south is very discernible. Using the detailed soil maps for a guide, this boundary was placed on the Landsat imagery. Landsat imagery shows many different patterns, some very dark, some light, and some with a mottled pattern. In the imagery used, soils appeared their natural color and vegetation appeared red. Tentative boundaries were drawn with pencil between areas where it appeared that different soil associations could be justified by color or pattern differences on the imagery. A review of the first draft showed that the soil associations were drawn too small and were too numerous. The second draft (Figure 1) was a refinement of the first draft. Small units were eliminated, lines were readjusted, and the composition and names of soil associations in terms of detailed soil map units was determined.

Results and Discussion

Landsat imagery offers a spectral view of a whole county on one colored photograph. One can compare soil patterns in any part of the county with those in any other part. The color of the Landsat imagery is also useful because two associations that may appear the same on a black and white photograph often have slightly different colors on Landsat imagery. Color also emphasizes light and dark patterns which makes placing association boundaries much easier.

A major benefit of the use of Landsat imagery for a base map is that lines can be drawn on Landsat imagery before the name of the soil association is determined. This method permits an independent evaluation of the soil landscape. Using the county road map as a base map requires that the soil association composition be predetermined so that the boundaries can then be placed on the road map.

Soil association boundaries can be placed more accurately on Landsat imagery than on a road map with no photographic pattern. Some soil areas shown on detailed maps do not fall clearly into any one association and Landsat imagery provides another vantage point for deciding into which association the area should be placed. The map prepared in this manner better represents the landscape than the previously published General Soil Map of White County (1).

Conclusion

In our opinion there is no method available by which we could make a general soil map as accurate as the one we made by using the Landsat imagery as a base map. We believe Landsat imagery is just as useful for making a general soil map as aerial photographs are for making detailed soil maps.

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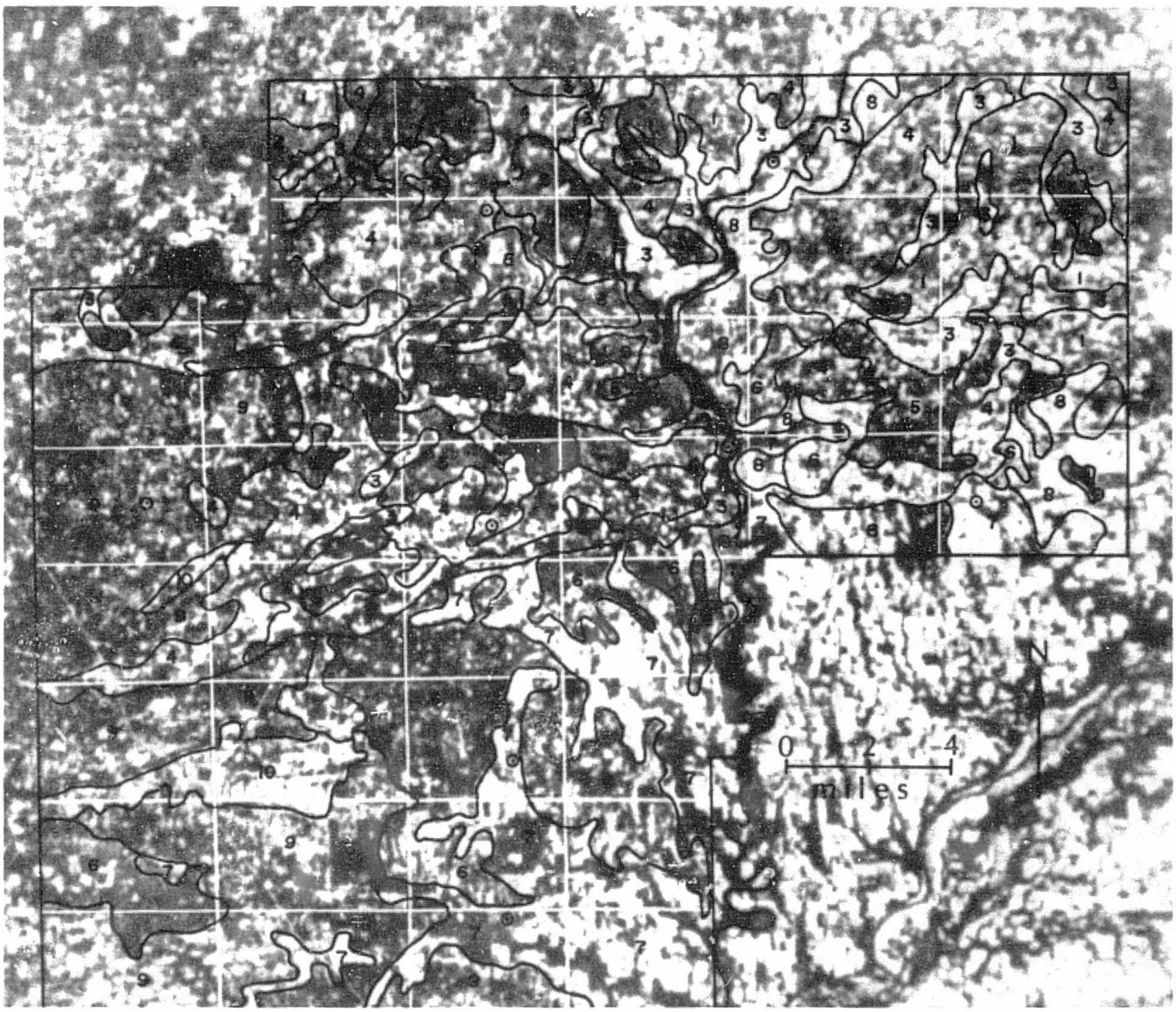

WHITE COUNTY, INDIANA
SOIL ASSOCIATIONS:

1. Maumee-Morocco
2. Maumee-Adrian
3. Chelsea-Oakville-Morocco
4. Gilford-Brady
5. Rensselaer-Gilford
6. Rensselaer-Whitaker
7. Martinsville-Whitaker
8. Aubbeenaubbee-Metea
9. Brookston-Conover
10. Montmorenci-Conover

Figure 1. White County, Indiana, General Soil Map.

ATTACHMENT 3

Inventory of a Nature Preserve Area in Lake County, Indiana Using Satellite MSS Data[1]

Introduction

The objective of this research was to investigate the application of computer-implemented analysis (2, 5) of Landsat data to recognize major vegetative cover and important physiognomic characteristics of species in a 121 hectare area of Lake County, Indiana. This area is characterized by a mixture of wetland prairie, dry prairie and oak savannas with over 300 different plant species (4).

Description of the Area

The study area, known as the Hoosier Prairie Nature Preserve, is a part of the remaining prairie in the northwestern part of Lake County, Indiana. It is situated in the former glacial Lake Chicago and the soil parent materials are primarily glacial till, lacustrine deposits, beach sands and gravels. Most of the soils are poorly drained with a relatively high water table such as Maumee fine sand or moderately well drained such as Brems fine sand. There are also some excessively drained soils such as the Plainfield fine sand with 0 to 6 slope.

Data Analysis Procedure

September 7, 1975 Landsat multispectral scanner (MSS) data obtained over the Hoosier Prairie tract located in the Griffith-Highland-Schererville area was used for analysis.

A nonsupervised clustering algorithm was used to analyze and group individual remote sensing units or pixels into clusters of similar spectral response. Although the Hoosier Prairie tract consists of only 121 hectares, a much larger area, 2172 hectares, was used for clustering to increase the spectral contrast so as to represent adequately all of the spectrally distinct features in the Hoosier Prairie tract. A statistics processor calculated the mean vector and covariance matrices for each cluster class in each of four wavelength bands. Using the statistics developed, a nonsupervised maximum likelihood classification algorithm was used to classify the area into 17 spectrally separable classes. Cover types were identified using a mean vector ratioing technique. This is a heuristic ratio:

$$A = \frac{V}{IR}$$

where V is the relative intensity of the visible wavelengths [(0.5 to 0.6μm) + (0.6 to 0.7μm)] and IR is the relative intensity of the reflective infrared wavelengths [(0.7 to 0.8μm) + (0.8 to 1.1μm)].

By summing the relative intensity values of all four bands the magnitude of relative spectral responses can be obtained as shown in the following equation:

$$\text{Summed response} = (0.50 \text{ to } 0.60\mu m) + (0.60 \text{ to } 0.70\mu m) + (0.70 \text{ to } 0.80\mu m) + (0.80 \text{ to } 1.10\mu m).$$

By observing the ratio A and the summed response, the analyst delineated major vegetation and land use categories within the Hoosier Prairie tract. Topographic, soil survey and geologic maps, aerial photography and limited ground observations also aided in determining the associations existing between spectral classes and ground features.

A hierarchical land use classification scheme similar to that developed by the U.S. Geological Survey (1) was followed (Table 1). Two broad Level I categories, vegetated and nonvegetated, were separated solely on the basis of their spectral responses. The mean vector ratios of the vegetated and nonvegetated areas were 1.00 or less and 1.10 to 1.30, respectively. The mean vector ratio statistics in conjunction with conventional photointerpretation of aerial photography were used to determine the Level II categories. At this stage the vegetated category was divided into vegetated residential, open land and Hoosier Prairie while the nonvegetated category was split into nonvegetated residential, industrial, and borrow pits.

Ground observations were used to further differentiate the Hoosier Prairie area into the Level III land cover categories of (a) herbaceous, (b) mixed herbaceous with woody plants and (c) woods and Level IV categories of (a) grasses on well drained areas, (b) grasses on poorly drained areas, (c) marsh-cattails and herbs, (d) marsh-shrubs and herbs, (e) brush, (f) scattered trees, (g) dense trees and (h) other.

Results and Discussion

The main effort of this study involved an assessment of the utility of the Landsat data to detect, identify, locate and measure features of the area of approximately 121 hectares known as the Hoosier Prairie Nature Preserve which has remained relatively undisturbed. Because of the complexity of the location and in order to obtain greater spectral contrast within the area, the investigation was expanded to include the metropolitan area of Griffith and open land to the north and cultivated land to the west of the Hoosier Prairie.

Within the entire study area two broad classes, vegetated and nonvegetated, were classified and their identification based upon their mean vector ratios. Nonvegetated terrestrial features exhibited high ratios due to high responses in the visible and much lower responses in the reflective infrared protion of the spectrum. Green vegetation exhibited lower ratio values due to high responses in the reflective infrared and low responses in the visible region of the spectrum.

Since the vegetative cover of the Hoosier Prairie represents a highly complex regime of native herbaceous, annual and perennial plants situated in colonies many times smaller than 0.5 hectare, the spectral resolution of Landsat, it is readily apparent that it would not be possible to delineate individual plant species using Landsat data. However, it was possible to classify the Hoosier Prairie area into 9 spectrally separable classes (Figure 1). These classes were separable due to differences in the type of vegetative cover, the density of vegetation and the wetness in the terrestrial ecosystems. By comparing the spectral classification to aerial photographs and field observations these nine spectral classes were interpreted to represent eight informational classes (Table 2). Figure 2 shows the relative spectral responses of the seven vegetative covers identified within the Hoosier Prairie tract. As the density of the vegetation increases (i.e., scattered trees vs. dense trees) the ratios decrease in value. Also it can be shown that vegetation on wet terrestrial ecosystems exhibit lower relative magnitude values than vegetation on dry ecosystems.

Conclusions

Nonsupervised computer-aided classification techniques employed to classify the Hoosier Prairie features with Landsat MSS data showed:

(1) Level I land use categories could be readily identified from Landsat data without the aid of supplemental reference material.

(2) All Level II categories could also be readily identified from Landsat data without the aid of reference material except for the residential classes occurring in vegetated areas. Photointerpretation of aerial photography was required to distinguish this class accurately.

(3) Identification of Level III and IV categories was possible by using ground observations to facilitate interpretation of the classification derived from Landsat data.

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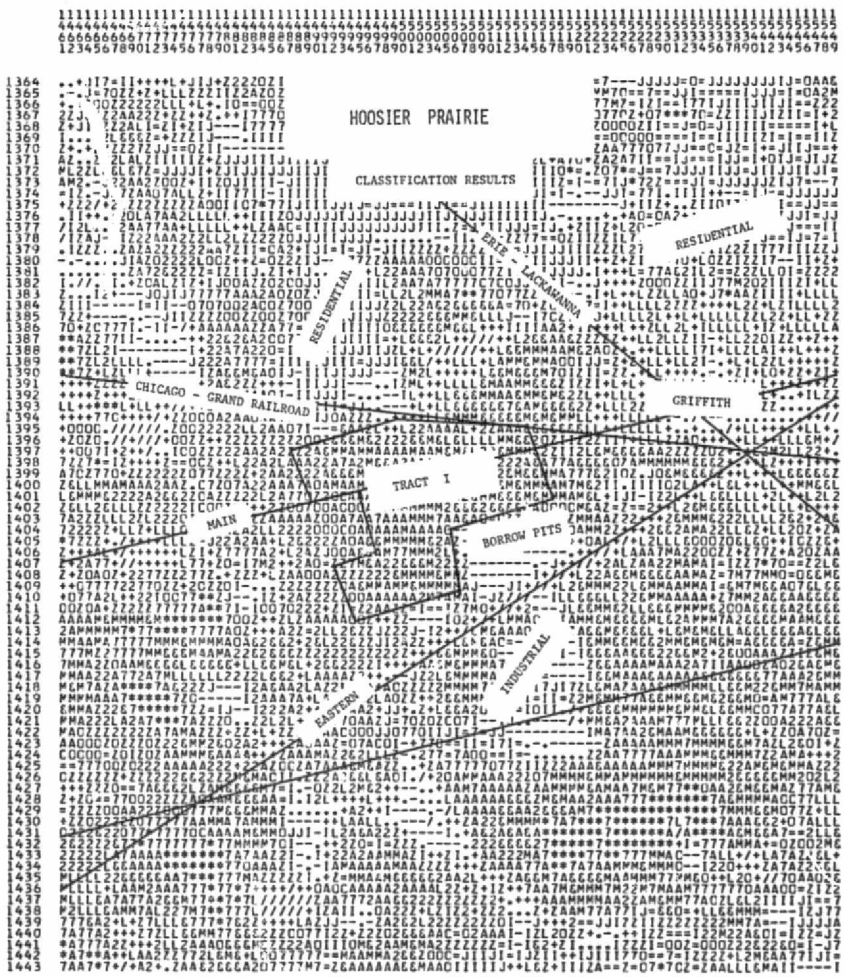

Figure 1. Spectral classification of the terrestrial environment of the Hoosier Prairie and surrounding area.

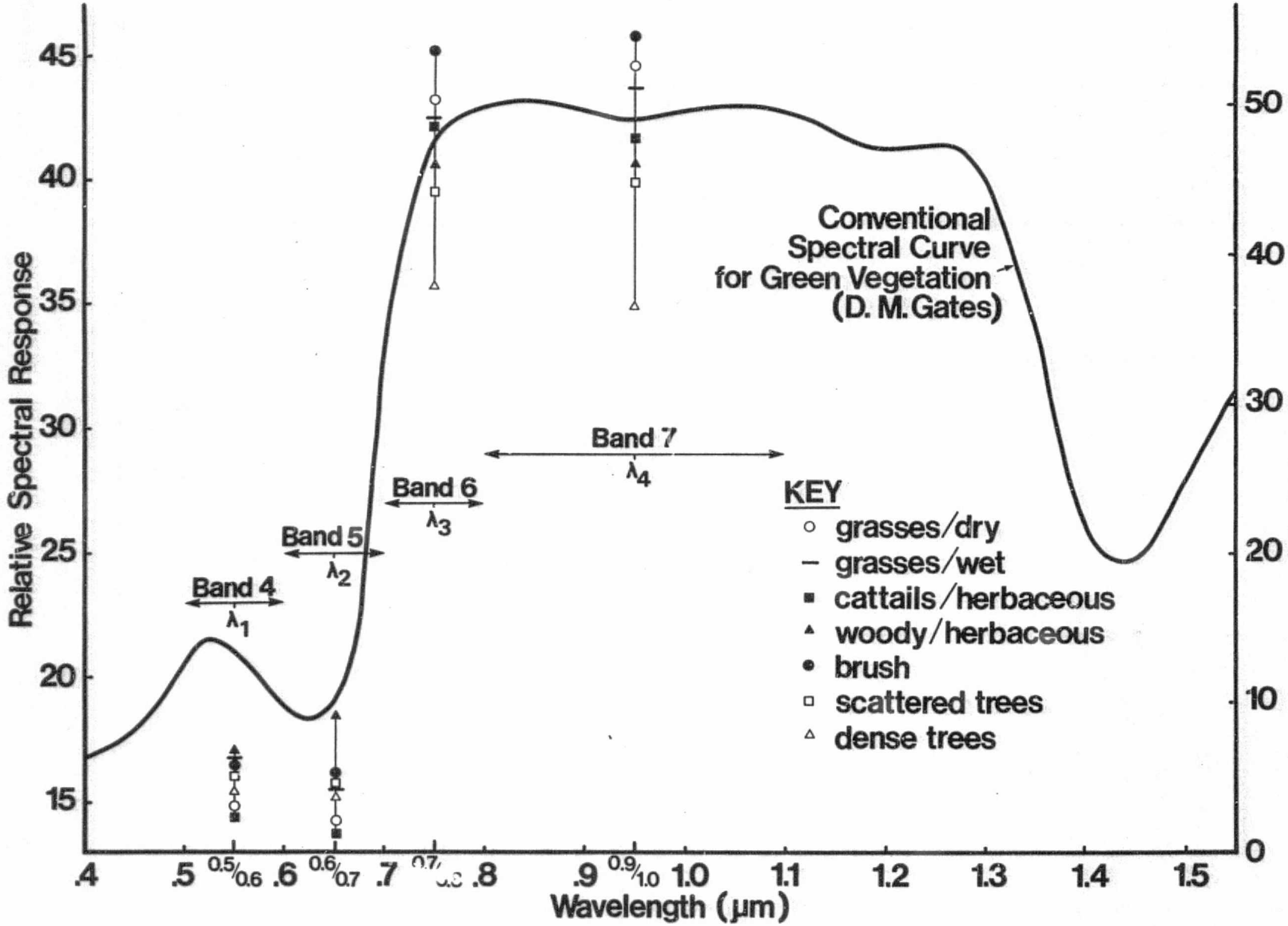

Figure 2. Relative spectral response obtained from seven different vegetative covers.

Table 2. Distribution of informational classes as determined from Landsat data.

	Spectral Symbols	Pixels	Percent	Hectares
Grass well drained areas	M	77	25.91	31.46
Grass of poorly drained areas	A	77	25.91	31.46
Marsh-shrubs/herbs	&	66	22.24	27.00
Marsh-cattails/herbs	Z	7	2.36	2.86
Brush	7	9	3.03	3.68
Scattered tree groups	2	41	13.80	16.76
Dense trees	L	11	3.72	4.50
Other	0,+	9	3.03	3.68
TOTAL		297	100.00	121.40

Table 1. Classification Hierarchy

Level I	Level II	Level III	Level IV
Vegetated	Residential	Old residential with trees of high density	
		Old residential with trees of low density	
		New residential with young trees	
		New residential	
	Open Land	Cultivated	
		Mixed	
	Hoosier Prairie	Herbaceous	Grasses of well drained areas
			Grasses of poorly drained areas
		Mixed	Cattails/herbs
			Woody/herbs
		Woods	Brush
			Scattered trees
			Dense trees
Non-vegetated	Residential		
	Industrial		
	Transportation		
	Borrow Pits		

FOREST TENT CATERPILLAR INTERPRETATION PROJECT

INTRODUCTION

Background

During the spring of 1975 personnel from Indiana's Department of Natural Resources reported large-scale defoliation of forest land in south-central Indiana. The defoliation, which affected parts of western Lawrence, northeastern Martin and extreme southeastern Green Counties (Figure 1), was caused by the forest tent caterpillar, Malacosoma disstria (Hubner)(Figure 2). The oaks (Quercus spp.) and maples (Acer spp.) are the favored host species of the caterpillar and also the mainstay of commercial forest timberland in this part of Indiana.

A major concern during early 1975 was that if the caterpillar population remained unchecked, continued severe defoliations would adversely affect the commercial quality of the timber. Field surveys were conducted during the spring and summer of 1975. Areas of defoliation were sketch mapped from a light aircraft and transferred to 1:24,000 USGS maps. Egg masses were collected in an attempt to predict population levels for 1976 and thereby estimate the severity of future defoliation and its resulting impact on tree growth. Figure 3 shows the approximate dispersion of tent caterpillar defoliation as mapped in 1975 (more detail is presented on the overlays to Figures 9 and 10). Results from field study of the defoliation and projected 1976 defoliation levels based on egg mass evaluation are presented in Table 1.

Evaluation of these data led IDNR personnel to believe that much larger-scale defoliation could be expected during the spring of 1976. Preventative measures, in the form of aerial sprays are possible but must be conducted while the insect is actively feeding during early spring. However, such measures could only be taken after the cost-benefit of the spray has been calculated and appropriate environmental impact criteria met. Results of the 1975 survey indicated that approximately 2400 hectares (6000 acres) were affected by 50 percent or greater defoliation. At this level the cost-benefit ratio was figured to be approximately 3:1 or such that a spray program would be economically infeasible.

Results from the egg mass survey, however, indicated a potential 70 percent increase, to approximately 10,000 acres, over 1975 levels. If indeed this were the case, a more favorable cost-benefit ratio would be anticipated and a spray would be conducted in the early spring of 1977. The problem confronting IDNR personnel was a rapid, accurate assessment of the area and intensity of the defoliation.

Objective

During early February personnel from IDNR met with members of the Laboratory for Applications of Remote Sensing (LARS) staff to determine if remote sensing could assist in evaluating the tent caterpillar damage. Initial discussions were directed toward determining if Landsat data could be used to assess the total effect of the 1975 defoliation. Since the area of concern

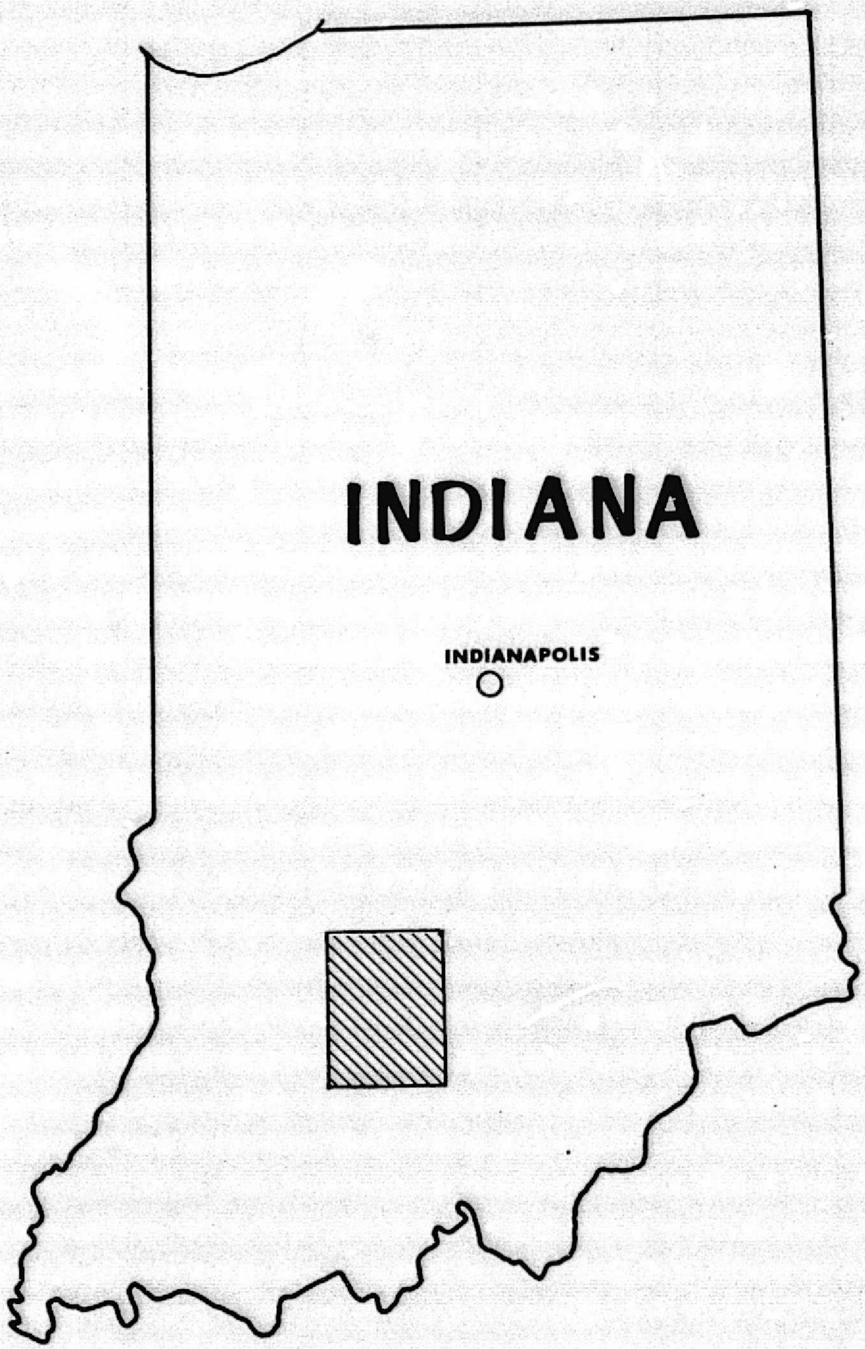

Figure 1. Area including parts of Lawrence, Martin and Green Counties which was affected by defoliation of forest tent caterpillar.

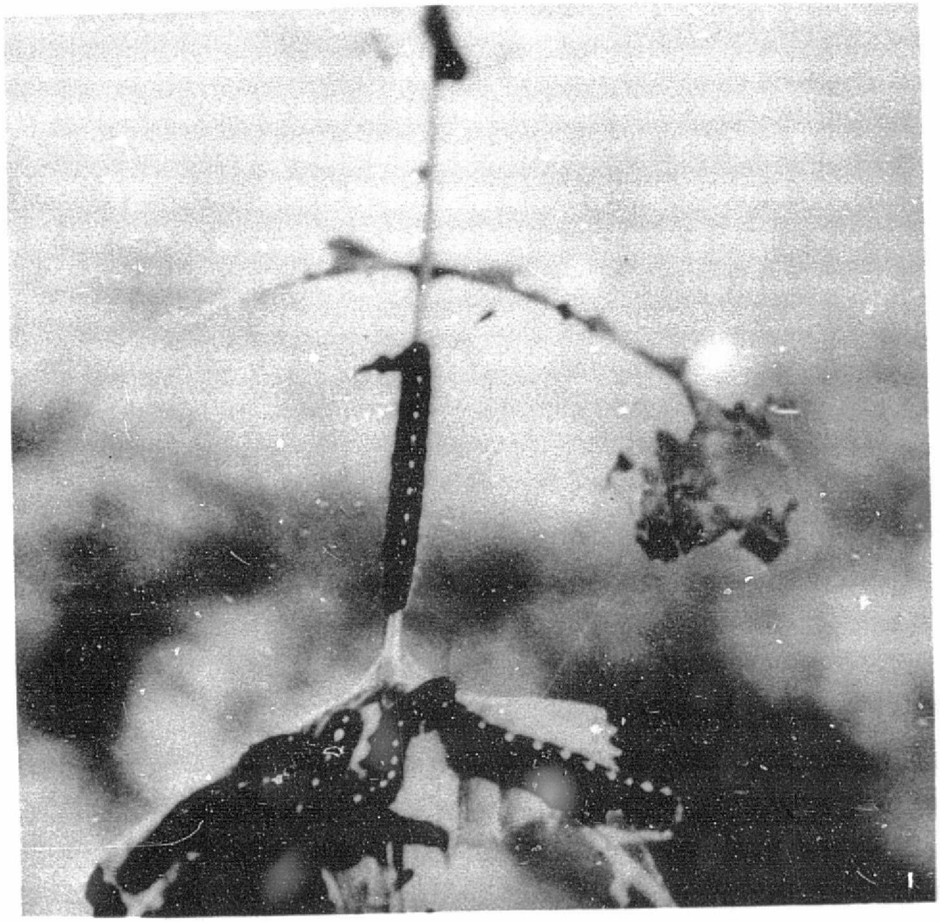

Figure 2. Larvae of the forest tent caterpillar, Malacosoma disstra (Hubner). Photo courtesy of the Indiana Department of Natural Resources.

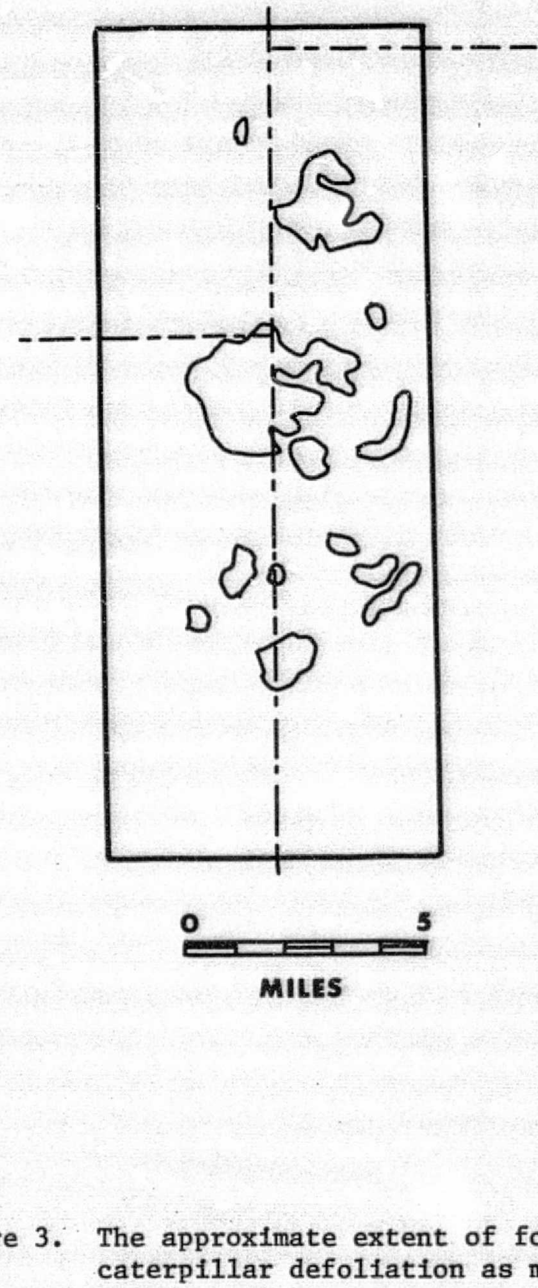

Figure 3. The approximate extent of forest tent caterpillar defoliation as mapped in 1975.

is fairly rugged and blocks of defoliation tend to be small, analysis of aerial photography was emphasized rather than the satellite data. Since IDNR personnel were familiar with color infrared photography and since LARS has a capability to collect photography, this appeared to be the most reasonable approach to the problem.

Personnel from IDNR and LARS working together developed a project objective as follows:

> To monitor the spread of forest tent caterpillar infestation on a commercial forest land in central Indiana and assess its impact on tree growth.

To meet the objective as stated, LARS staff would collect the aerial photography and provide the photo-interpretation results. IDNR staff would be involved in collecting field data, provide input to developing photo-interpretation keys and be responsible for writing environmental impact statements if the results so indicated. Additionally, LARS staff would provide support where appropriate.

Test Site

The primary effort would be centered around the area of known 1975 infestation (Figure 4). If preliminary indications warranted, a larger sample area (outside line of Figure 4) would be flown and interpreted. The intensive study site includes parts of Green, Monroe, Lawrence, and Martin Counties. Also included within the study area is a part of the Naval Weapons Support Center, Crane, IN. The sample area covers approximately four times the intensive study area extending from Lake Greenwood on the west to Bedford on the east and from approximately Paoli at the south to Bloomington at the north.

The test areas can be characterized as predominantly rugged, having been formed over Illinois aged till. Agricultural land occurs primarily along the floodplains, with some abandoned fields scattered along the ridgetops. Forest predominates as the major land use. The oak-hickory covertype is dominant along with mapes and other common hardwoods. Generally, the area can be considered as a typical central hardwood association.

Ownership of much of the area is private, but falling within the purchase boundary of the Wayne-Hoosier National Forest, and federal, i.e., the Naval Weapons Support Center. Some State land was included in the test area (Martin County State Forest).

Methods

Previous experience indicated that defoliation caused by insect feeding reaches a peak in early to mid-May. Variation in times occur based on the arrival of spring warm-up. The Purdue aircraft outfitted with LARS twin Hulcher 105 cameras with matching 38mm Ziess Biogon lenses would be on standby during most of May. The aircraft would be deployed after field assessment indicated that insect feeding was at a peak.

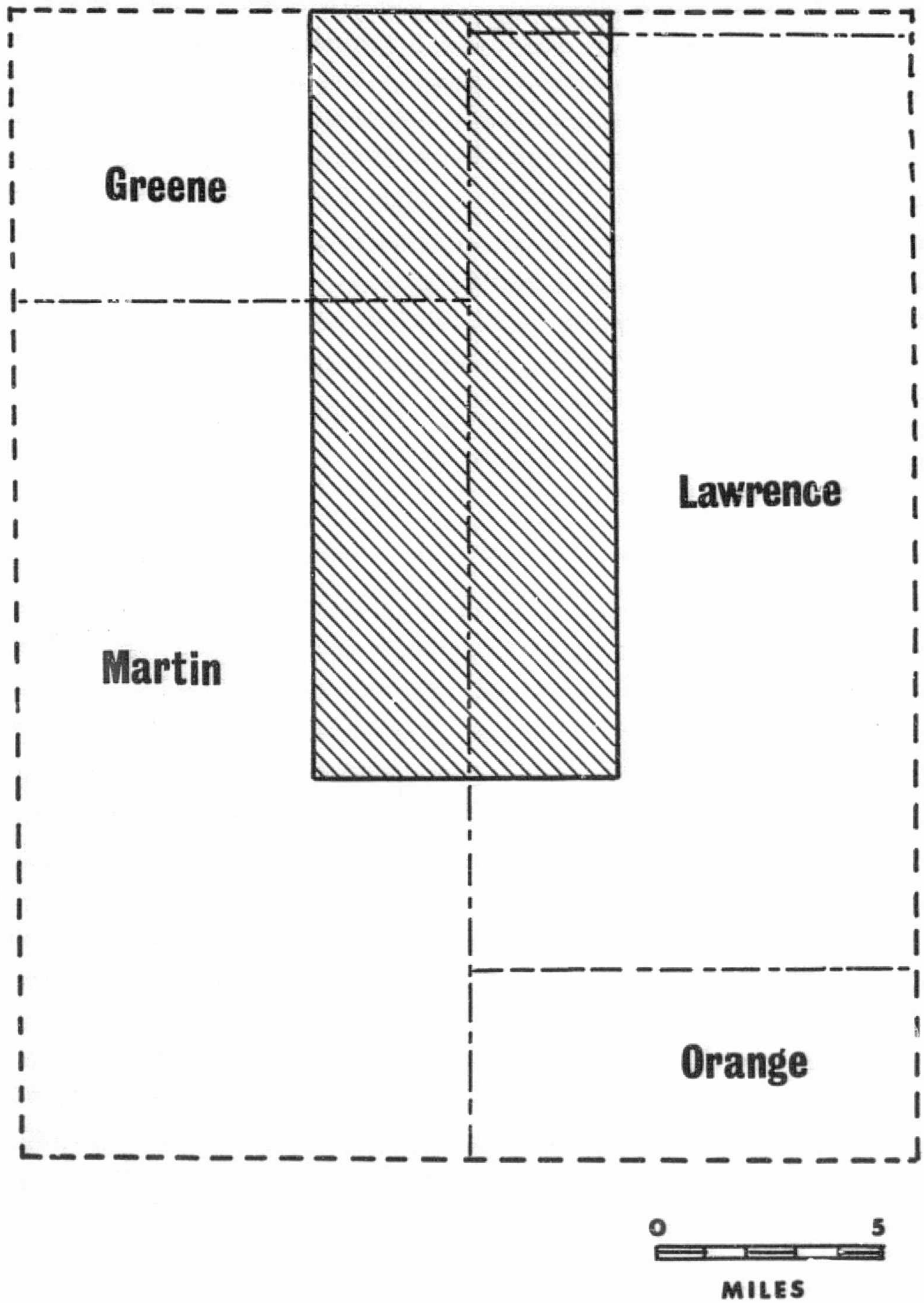

Figure 4. Test area overflown in 1976 with color infrared photography. The shaded area represents the extent of the 1975 defoliation and the intensive test site. The remaining area outlines the sample site.

Normally, the twin cameras are outfitted with different film types, usually normal color and color infrared. However, for this mission both cameras were outfitted with Kodak Aerographic Infrared (type 2443) 70mm film. The haze penetration characteristics of the color infrared combined with its inherent sensitivity to chlorophyll deficiency made it the obvious choice for interpretation. Since we had decided to collect relatively large scale photography (1:36,000) with 60 percent forward and 30 percent side overlap, we were concerned that one one-hundred foot roll would be insufficient to cover both the intensive study site and sample site. For these two reasons both cameras were loaded with color infrared film. Shutter speeds were preselected on the ground. Exposure would be varied in flight based on reflect reading from the ground scene, and aircraft speed. Both cameras were outfitted with Wratten 15 gelatin filters. To enhance image contrast a lens aperature was selected which would give ½ stop underexposure. Aircraft altitude was selected at 5,000 feet absolute and all flightlines were flown north so that film illumination would be uniform. A burst of four frames was fired prior to the first flightline as a processing test, and a last failsafe in case any other variable had been overlooked.

The flight plan was to overfly the intensive study area first and then fly the larger sample site. The larger site was so named because complete coverage would not be obtained. Approximately one of every three flightlines would have data collected over it. The requirement for 60 percent forward overlap would be retained. However, only a sampling of stereopairs would be analyzed and results of this analysis expanded back to the entire site. With both sets of photo data we felt reasonably sure that any inference drawn about the insect population would be accurate.

After the film had been exposed, processed and returned to LARS, it would be evaluated for quality and if necessary reflown. If no reflights were to occur, then photo-interpretative keys would be developed with the aid of IDNR personnel.

Photo-interpretation Key Development

Photo-interpretation keys were developed to include the range of conditions present in the test site. Three conditions of defoliation, light, less than 25 percent, moderate, 25 to 75 percent, and heavy, greater than 75 percent defoliation were known to exist on the ground sites. Figures 5 through 7 are representative examples from the photo key along with a description of the defoliation.

In addition to defoliation caused by the forest tent caterpillar, die back due to frost damage was also present on the site. Spring flush began with an exceptionally warm March. This condition continued through early April when a severe frost occurred, even in the southern part of Indiana. The frost, which repeated for two or three nights, effectively killed back the early flush of growth. Second growth had not progressed enough by mid-May to affect the response of the color infrared film. In effect, frost damage appeared similar to insect defoliation. The frost damage, however, progressed only midway upslope. Insect defoliation would be noted up to the ridgeline. The relationship of the damage to slope position was the only clue the interpreter had in separating the two effects. A representative example of frost damage is shown in Figure 8.

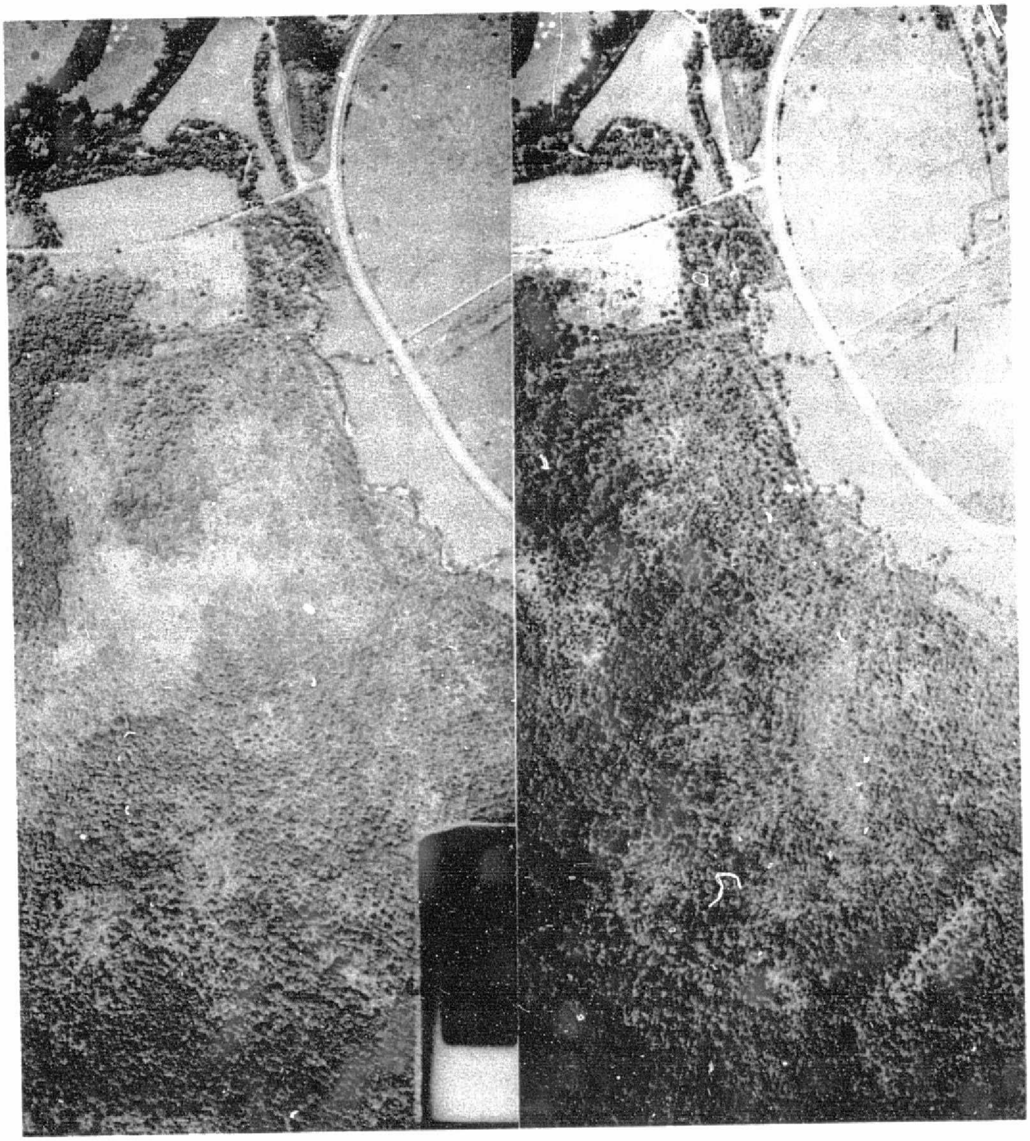

Figure 5. Stereogram of an area which exhibits the effects of light insect defoliation. Indicators used by the interpreters to distinguish this level of insect feeding from frost damage was a distinctive pink color cast associated with insect defoliation and the fact that frost damage never crossed topographic ridges. (Original photography in color)

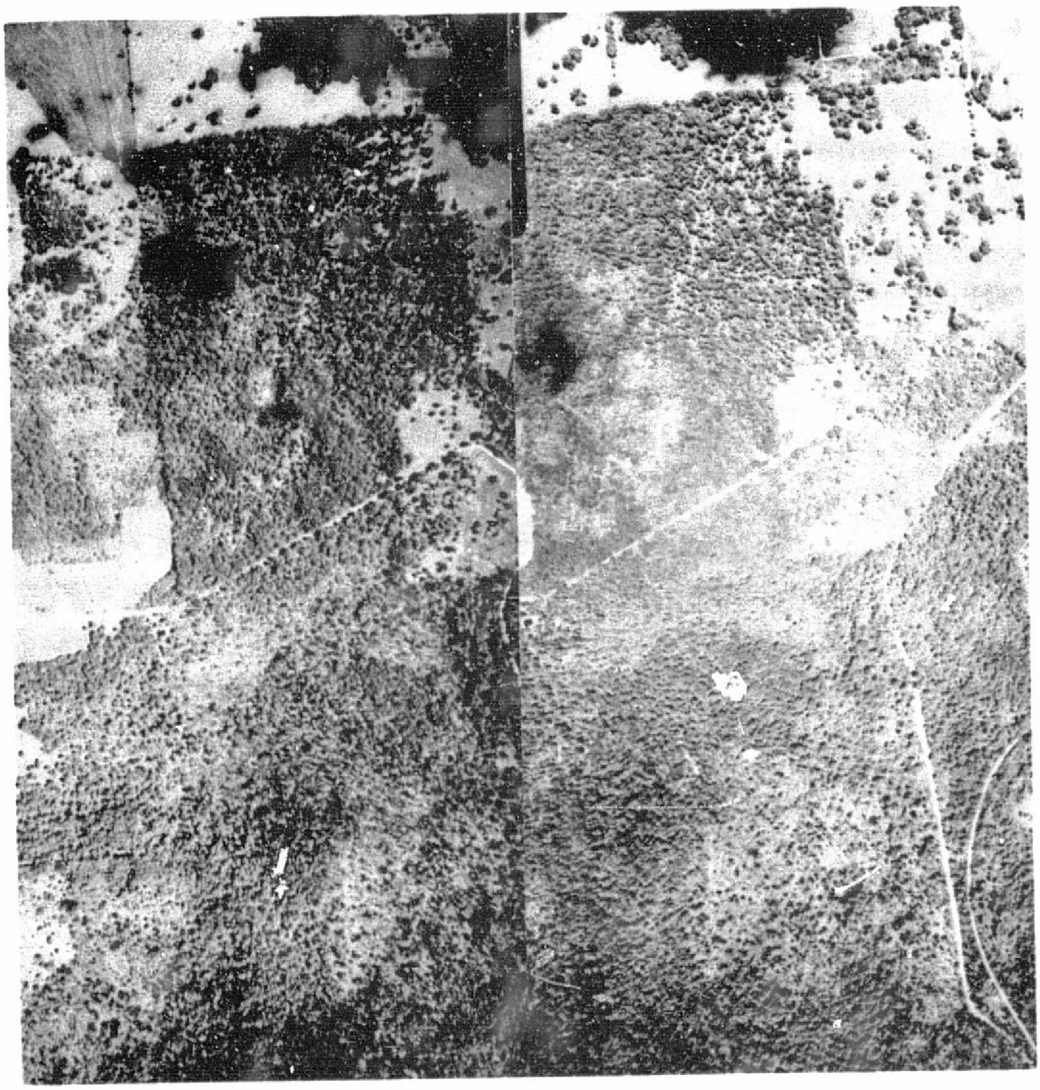

Figure 6. Stereogram of an area with moderately heavy insect feeding. This class is characterized by the amount of understory visible through the crown. On the original photography the area will appear a brownish-red compared to the surrounding vegetation. (Original photography in color.)

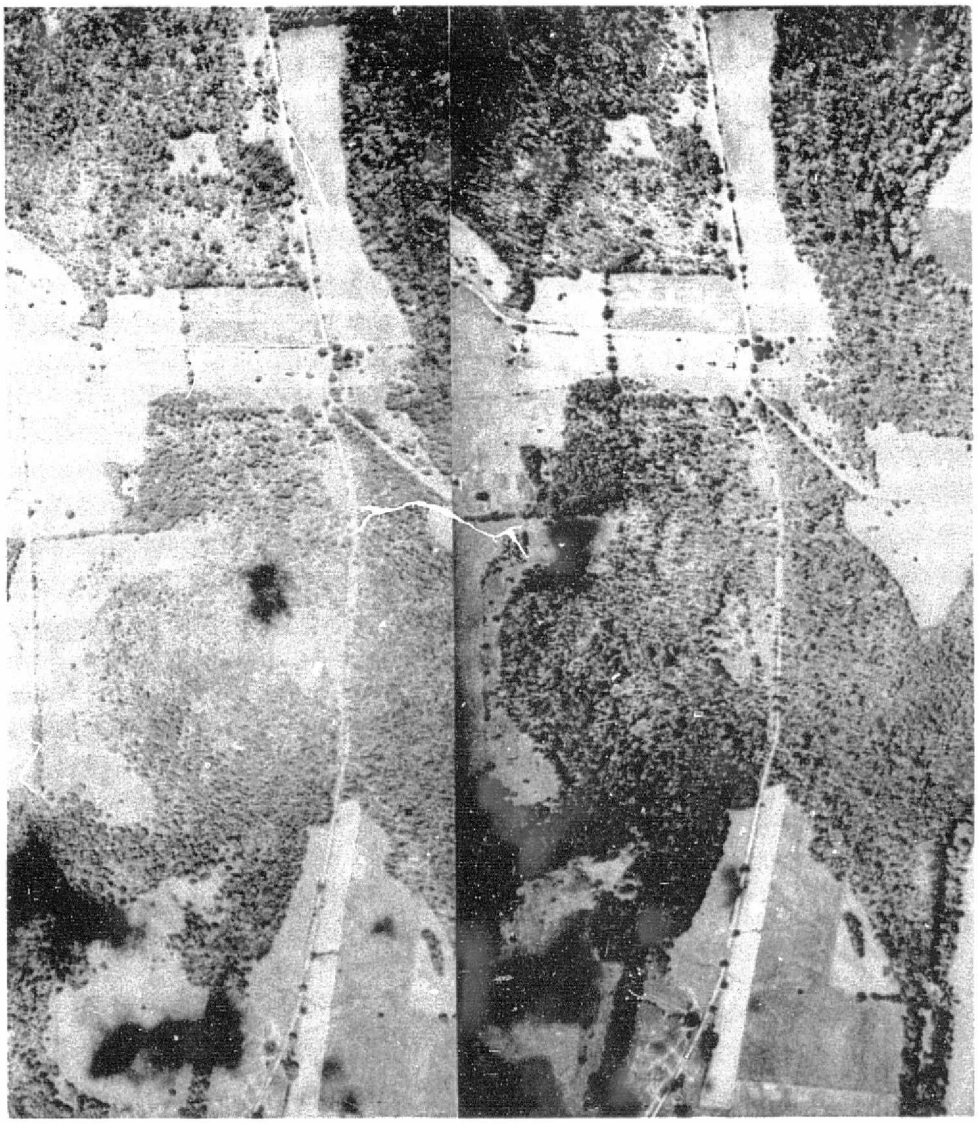

Figure 7. Stereogram of an area in which there is extensive heavy feeding by the tent caterpillar. Close examination of the photo pair indicates standing trees completely defoliated. (Original photography in color.)

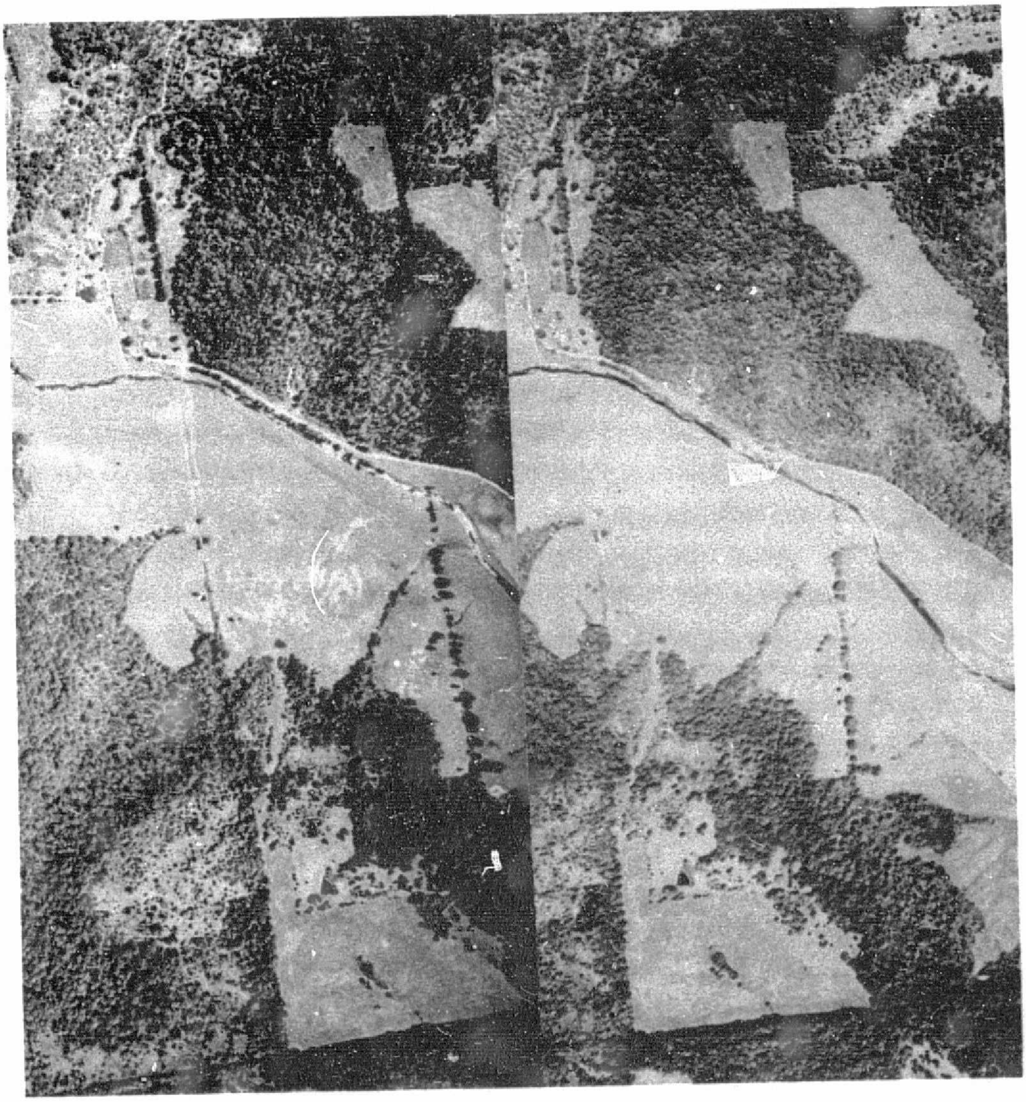

Figure 8. Stereogram of an area which shows a good example of frost damage. In addition to tonal cast frost was most easily identified because it progressed only half way upslope whereas insect defoliation would continue to the ridgeline. (Original photography in color.)

The photo keys, representative stereo pair, description and topographic map of location were mounted in manila folders. The folders were marked and grouped according to damage level. Interpreters would review the photo keys before doing any flightline interpretations. The keys were available to check as reference as needed during the interpretation. A Baush & Lomb Zoom 95 Stereoscope was available for use but was cumbersome to use with the 70mm strip film. The dimensionality provided through stereo viewing, therefore, was not utilized. Interpretations were manually sketched on USGS 1:24,000 quadrangle sheets and later planimetered for acreage.

Since the sample area photography was not collected at the same time as the intensive study site photography, due to deteriorating weather conditions, a different analysis approach was utilized. In addition to being taken a month later the sample area photography was collected at 10,000 feet absolute (scale 1:72,000). For this data the areas which had been most heavily affected were the only areas identifiable on the photography. A dot grid was constructed and dots falling in the obviously affected areas were tallied. Again, the stereo capability was not utilized so every other photo of every flightline was tallied.

Field data was collected by IDNR personnel and included such items as a measure of the reduction in growth increment, mortality loss and extent of insect feeding. Data were collected for insect egg masses, parasites and predators and diseases of the caterpillar, and wildlife characteristics of the affected areas. All these parameters would be necessary in preparing the proposal for the aerial spray and its environmental impact statement.

Results

Figures 9 and 10 show the intensity of insect defoliation as mapped from aerial photography on the Owensburg and Williams 7½ minute USGS quadrangle sheets. The numbers on the map relate to defoliation intensity as follows:

0 = defoliation due to frost damage
1 = light defoliation (under 25 percent crown thinned)
2 = moderate defoliation (between 25 and 75 percent crown thinning)
3 = heavy defoliation (greater than 75 percent crown thinned)

The areas coded by a fraction (e.g., ½) represent a transition between two categories.

The overlays to Figures 9 and 10 represent the spread of defoliation mapped during the 1975 season. These are included as a comparison to the photo-interpreted results. The numbered dots on the overlays represent the ground plots referred to in Table 1. Derivation of Table 2 is worth consideration.

Results from the intensive study site were interpreted from the 70mm color infrared and visually transferred to the USGS maps. These areas were then planimetered, and those measures converted to acres. These acres were expanded to the sample site by applying a correction factor to the intensive study site data. The correction factor was derived as follows:

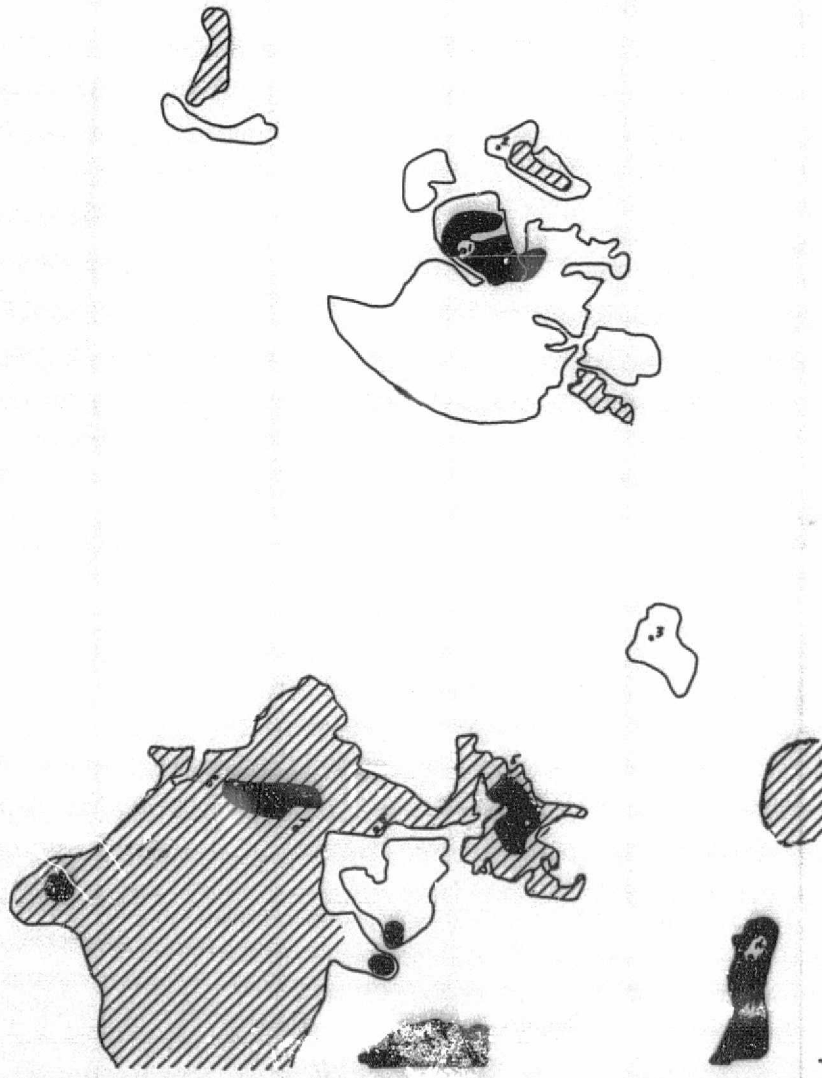

Figure 9. **Owensburg, Indiana quadrangle sheet showing defoliation due to forest tent caterpillar feeding. Refer to text for meaning of number code. The overlay shows the extent of 1975 defoliation. The black being the most severe while the light is least severe.**

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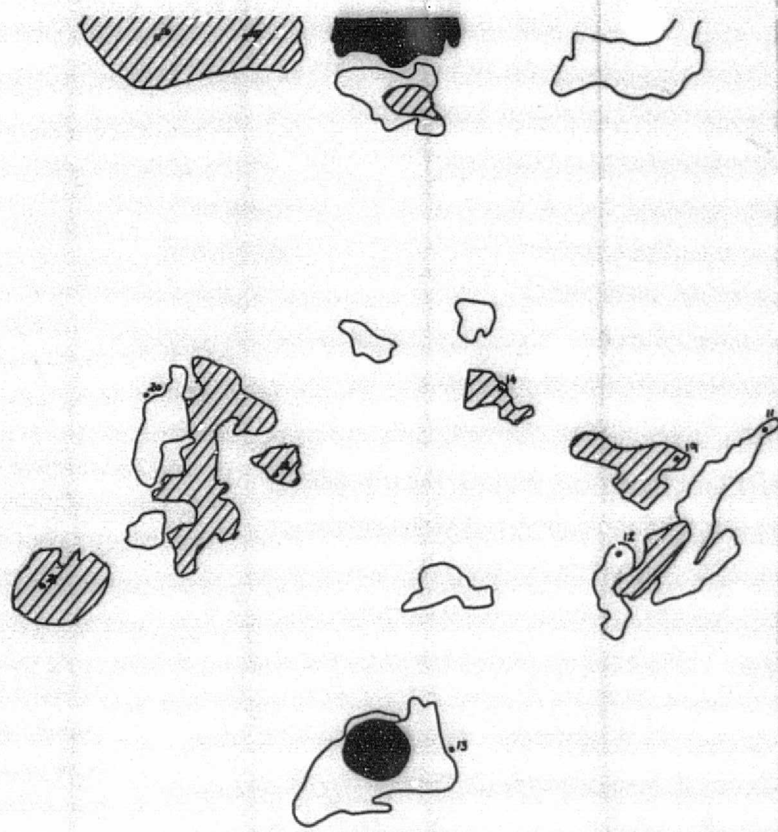


Figure 10. Williams, Indiana quadrangle sheet showing defoliation due to forest tent caterpillar feeding. Refer to text for meaning of number code. The overlay shows the extent of 1975 defoliation. The black being the most severe while the light is the least severe.

Table 1. Actual and Predicted Defoliation Level for Forest Tent Caterpillar, 1975, 1976 & 1977, by Plot.†

Plots #	1975 Actual	1976 Predicted	1976 Actual	1977 Predicted
1	Heavy	Heavy	Heavy	Light
2	Moderate	Moderate-Heavy	Heavy	Light
3	Light-Moderate	Light-Moderate	Moderate-Light	Light-Moderate
4	Moderate	Heavy	Moderate-Heavy	Light-Moderate
5	Heavy	Heavy	Heavy	Light
6	Moderate	Light	Light	Light
7	Moderate-Heavy	Moderate-Heavy	Heavy	Negligible-Light
8	Moderate-Heavy	Light-Moderate	Heavy	Moderate
9	Light	Light	Negligible	Light-Moderate
10	Moderate	Moderate	Heavy	Moderate
11	Light	Heavy	Moderate-Heavy	Negligible-Light
12	Light	Moderate	Negligible	Negligible
13	Light	Moderate-Heavy	Moderate	Heavy
14 *	Moderate	Heavy	Heavy	-----
15	Light	Light	Light	Moderate-Heavy
16	Heavy	Moderate-Heavy	Heavy	Negligible-Light
17 *	Heavy	Heavy	Heavy	Light-Moderate
18	Moderate	Heavy	Heavy	Light-Moderate
19 *	Moderate	Moderate-Heavy	Light	-----
20	Light	Moderate-Heavy	Moderate	Moderate
21	Moderate	Moderate-Heavy	Heavy	Light-Moderate
22 **	-----	-----	-----	Negligible
23 **	-----	-----	-----	Negligible
24 **	-----	-----	-----	Moderate
25 **	-----	-----	-----	Moderate

* Logging occurred in these plots between time prediction made and actual survey for defoliation in May, 1976.

** Established 1976.

† Prepared from IDNR field survey information.

Table 2. Forest Tent Caterpillar Defoliation.[1]

	Defoliation Levels (number of acres)			Total
	Heavy	Moderate	Light	
1975 Survey	585	3430	2121	6136
1976 Survey (Intensive Site Results)	3577	3930	7618	15125[2]
Expanded to Sample Site	3639	4193	8200	16032[3]

[1] Frost damage accounted for 2143 acres on the May 15, 1976 photography. Correction for the sample site indicated probably 2189 acres were affected by frost.

[2] Total acres interpreted in the intensive study site equals 61600.

[3] Total acres represented in the sample survey area were 308288.

$$CF = \frac{\text{\% total area of heavy defoliation at } T_2}{\text{\% total area of heavy defoliation at } T_1} \times \text{\% total area of heavy defoliation at } T_1$$

where

CF = Correction factor
T_2 = Photography taken June 15, 1976
T_1 = Photography taken May 15, 1976

A correction factor was necessary because the date the sample photography was taken was a month later than the intensive site data. Since we were confident that the results of the heavy defoliation were still identifiable at T_2 (Figure 11), these data were used to develop the correction factor. The correction factor was applied as follows:

CF x Acres defoliated in each level = Expanded defoliated acres.

Application

The obvious application of this data in combination with the field data would be as support for an aerial spray during the spring of 1977. However, preliminary results from this summer's egg mass surveys indicate that insect populations are in a declining phase and will be at lower epidemic levels in 1977. The aerial data also indicates no spread outside the boundaries of the intensive study area. Based on this information an aerial spray is not warranted.

However, field and aerial surveys also indicate substantial mortality has occurred in areas of moderate to heavy insect feeding. The problem is apparently of severe enough proportions for the State to recommend that salvage operations be initiated. Results of the interpretations of the May 15, 1976 overflight of the intensive study site will be used to assist in the timber salvage operations. Maps will highlight areas of severe defoliation where widespread mortality might be expected to occur.

Additionally, photography from both aircraft missions will be available to IDNR personnel to assist in whatever way possible. At this point in time it is important to expedite salvage operations in whatever way possible. Standing dead timber is prone to damage by either insects and pathogens which will decrease the stumpage value.

Conclusions

Color infrared photography collected during peak feeding by the forest tent caterpillar is an effective means of monitoring the damage spread. Although three dimensional viewing capabilities would be desirable, they are not absolutely necessary if good topographic maps are available. Scale does not appear to be a critical variable to the interpretation; whereas, film exposure does. Improperly exposed film will create difficulties for the photo-interpreters. For this study under exposure of approximately a half stop from the indicated exposure gave very good results.

Figure 11. This photograph is an example of the sample area photography collected June 15, 1976. The marked areas represent the heaviest level of defoliation during the peak feeding period. These areas are now beginning to put on new growth and appear different than the surrounding vegetation. (Original photography in color.)

Discussion

As with many of life's activities, one always feels more inspired after an occurrence than before. This hindsight, hopefully, from a point of objectivity, leads to the following discussion points:

- The Purdue aircraft is outfitted with 70mm format cameras with wide angle lenses. To obtain relatively large scale photography, without incurring expensive enlargement costs, low acquisition altitudes are necessary. Weather conditions were such that the aircraft was severely buffeted which affected the image geometry. A larger aircraft having a 9 - inch format camera would have been a far superior data collection vehicle.

- The entire test site, including both the sample and intensive study areas whould have been overflown at the same time or minimally within a week's time. This would have prevented applying a correction factor which assumes a ground condition existed at T_1 from information derived from T_2. A better estimate of actual ground conditions would have been inferred if all the data had been collected during mid-May.

- The appropriate equipment was not available for stereo interpretation. This added third dimension would have made assessment of frost damage much easier for the interpreters.

- Initial indications are that Landsat data does not provide sufficient information for this type of remote sensing activity. Weather conditions at peak assessment times and timeliness of acquiring data from the EROS data facility preclude this tool as an applicable approach. Deployment of State or contract aircraft to map peak defoliation periods would appear to be a more reasonable approach.

Acknowledgements

Numerous individuals have been involved in some aspects of this project. Special thanks are due Phil Marshall, Forest Pest Specialist, IDNR, for his assistance in identifying test areas, providing maps, ground reference information, and for developing the photo-interpretative keys. Also the interpreters, Lisette Ernst and Steve Noyer, graduate students at Purdue University, deserve thanks for the hours they spent interpreting, planimetering and in general providing the results to this project. Appreciation is also expressed to Forrest E. Goodrick, LARS, for his assistance and guidance in collecting the aerial photography.

WETLANDS MAPPING PROJECT

INTRODUCTION

During the Spring of 1976 personnel from LARS met with members of Indiana's Department of Natural Resources, Division's of Property, Fish, and Wildlife. The outgrowth of these meetings was the development of a photo-interpretation project directed at supplying information about the vegetative complexes in the Tri-County Fish and Wildlife Area (TCFWA).

The Tri-County Fish and Wildlife Area is a 1360 hectare (3400 acre) block of land located in the southeast corner of Kosciusko County, Indiana (Figure 1). The site lies to the south of a small chain of natural lakes, the largest being Lake Wawasee. Because of its location, close to a large body of water, and its position along a major waterfowl flyway, goals of TCFWA management are aimed at improving waterfowl habitat.

In pursuit of this goal, IDNR has taken positive steps toward altering the vegetative complex of the area. The water table was modified, where possible, to favor vegetative species which ducks and geese prefer for nesting and feeding. The results of these activities are difficult to assess from the ground. However, it is most important that these results be assessed to determine their effectiveness.

OBJECTIVE

Given the above considerations, the following task objective was defined:

> To map the components of the wetland wildlife habitat in and in the area surrounding the Tri-County Fish and Wildlife Area.

These components correspond to the different vegetative covers which animals, principally waterfowl, use for feeding, roosting and nesting. The final product from this activity would be a vegetative type map.

The application of this map, as defined by the Tri-County Fish and Wildlife Area (TCFWA) Property Manager, is twofold. The Indiana Department of Natural Resources does not have an accurate estimate of the acreage of wetland habitat nor the location of wetland habitat within the TCFWA. The first purpose of this map then is to define and measure the extent of wetland habitat in the TCFWA. LARS would be responsible for defining vegetative areas. IDNR would assume responsibility for the area measurements.

The second application involves use of the map as a management tool. In 1974 a portion of the TCFWA was drained to encourage emergent plant growth a means of waterfowl habitat improvement. In the summer of 1976, the water level of this area was raised. The property manager must now assess the results of the draw-down. He must estimate the acreage of new habitat produced, decide whether to continue this management practice, and he must decide where future draw-downs are to be located. The wetlands covertype map should aid him in these decisions.

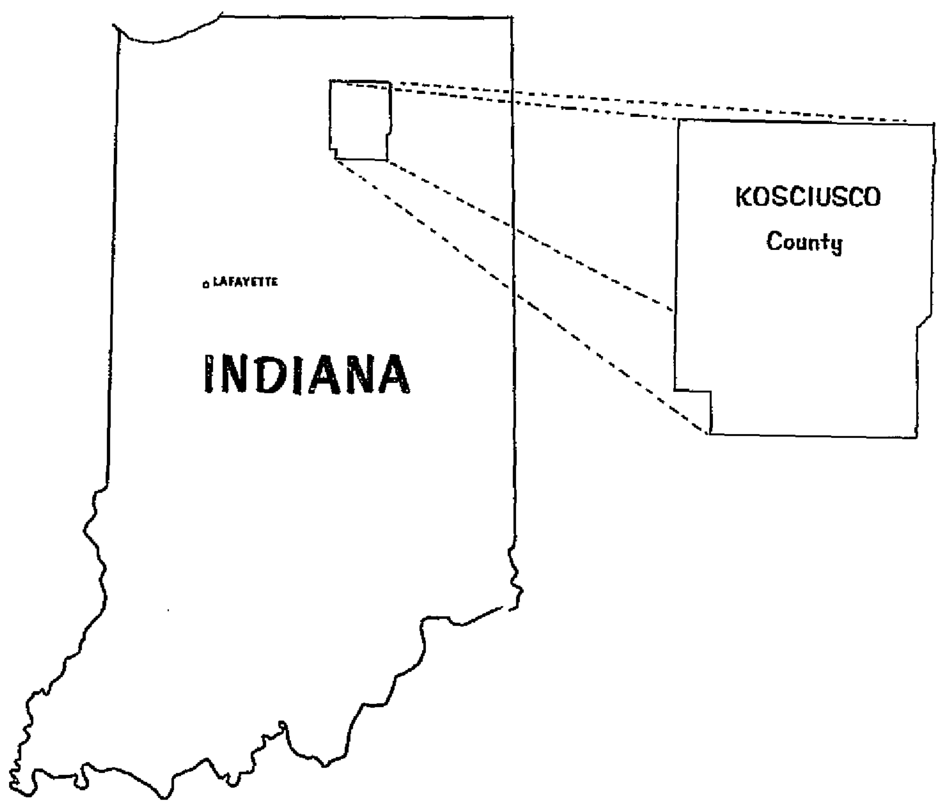


Figure 1. Location of the Tri-County Fish and Wildlife Area.

MAPPING PROCEDURES

Color infrared aerial photography was collected over Lake Wawasee and the Tri-County Fish and Wildlife Area in July 1976. Several frames of photography were chosen as potential training samples for the mapping exercise (Figure 2). These frames were enlarged and printed for field reconnaissance. The enlargements were taken into the field and compared to the actual ground cover. The photo-interpreter defined the specific photographic features which were associated with a particular ground cover. Eight covertypes were defined in the field. The photographic features associated with these covertypes and a description of each covertype are given in Table 1.

THE COVERTYPE MAP

The final covertype map (Figure 4) was drafted on mylar for easy reproduction. The scale is approximately 1:10,000. The smallest unit mapped is approximately three acres in size.

DISCUSSION

Aerial photo-interpretation is an efficient, effective method which can be used to monitor changes in habitat composition. With such technology land resource managers can be provided with information of a quality that will reflect wise use decisions. The technology applied in this study is not beyond the means of any resource management agency to acquire. Various authors (1,2,3,4) have identified the tools necessary to obtain aerial photographs from light aircraft. Equipment no more sophisticated than what can be purchased at a well outfitted camera store is being used to conduct operational air monitoring surveys (2,3,4).

The interpretation of these data can best be handled by individuals familiar with the terrain. Resource managers have latent abilities as photo-interpreters that are rarely brought to bear in their day-to-day management activities. An individual familiar with the terrain and study objectives could have completed this project in at least half the time than was necessary for our interpreter. Obviously, proximity and familiarity with the site are a great asset.

RESULTS

The ultimate evaluation of the applicability of this map rests with the Tri-County Fish and Wildlife Area Manager. If the map fulfills an information need and therefore assists him in a management decision, the task was successful. Until that assessment is made, the following reflections are appropriate.

- Aerial photography has been shown to be an efficient means of mapping waterfowl habitat types.

- Mapping this site from aerial photos was a relatively quick process with a small portion of the total time devoted to field reconnaissance.

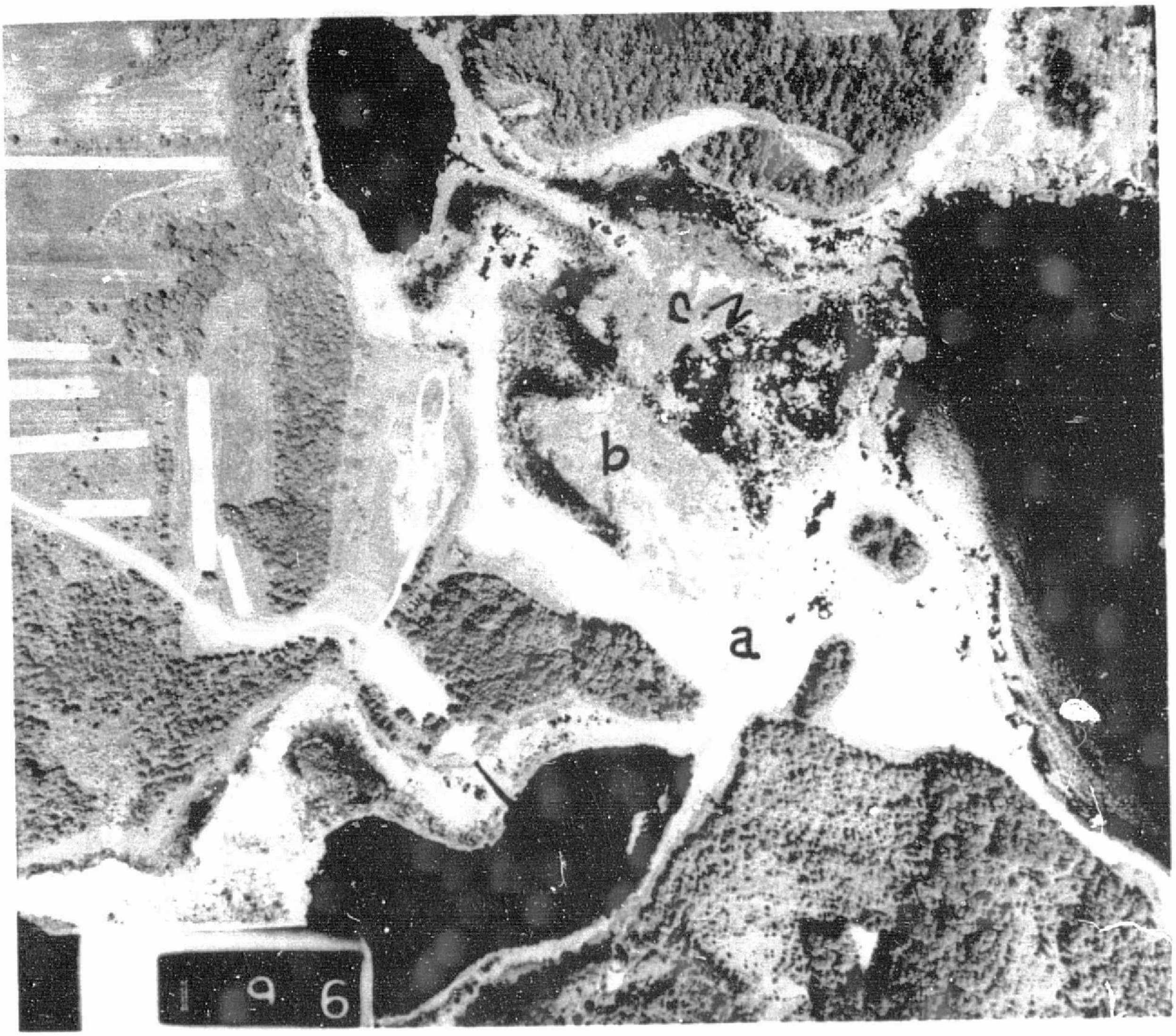
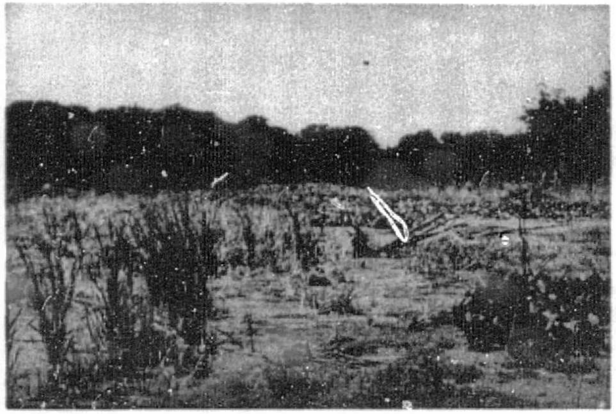
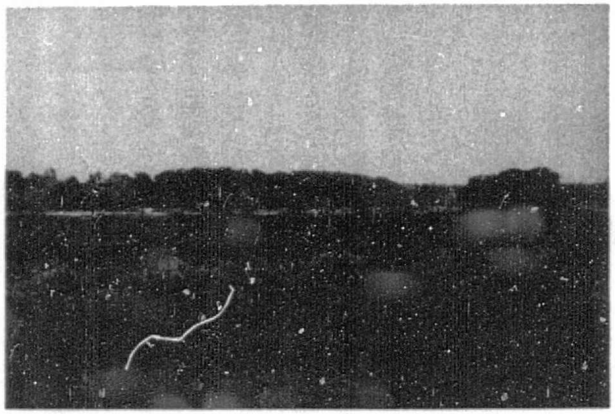


Figure 2. An example of the imagery collected over the Tri-County Fish and Wildlife Area for assessment of vegetation communities. Original photography is color infrared. Symbols refer to the ground photos in Figure 3.

Map Symbols	Description
(a) Fd	- Duckweek/floating algae/young grasses interspersed with small patches of spatterdock and cattails. Corresponds to (a) on B & W photo 196.
(b) Ms	- Low shrubs/grasses. A typical example of this covertype. Corresponds to (b) on B & W photo 196.
(c) Fc, Fs, Mc	- In some areas several covertypes occur interspersed within each other. In this photograph spatterdock/duckweed/cattails/dead tree snags occur together. The result on the air photo is a blending of gray, pink, white and brown which gives a mottled effect. Corresponds to (c) on B & W photo 196.





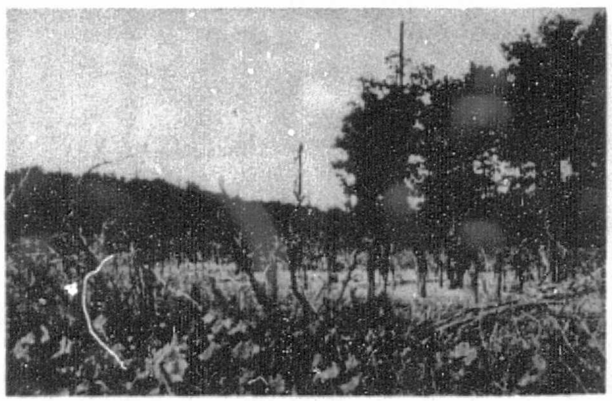


Figure 3. Representative ground shots of covertypes identified in Figure 2.

Table 1. Covertypes mapped in the TCFWA which appear on the map in Figure 4. Mapping was based on interpretation of large scale color infrared aerial photographs.

Covertype	Photographic Features	Ecological Description
Water	Dark blue to black in color Smooth texture	Suspended sediments or a light sandy bottom may result in lighter shades of blue.
Submerged Vegetation S	Light to medium brown color Smooth texture	Submerged vegetation was noted only along the lake shoreline. It is noticeable only in clear water with a light sandy bottom at depths of less than four feet and at low sun angles. Because of the number of factors which must coincide for the vegetation to be apparent on a photo, submerged vegetation is difficult to map. On this covertype map, the areas shown as submerged vegetation should be viewed as probable areas of submerged vegetation, but not as the only areas. Other areas do exist, but they are not apparent on the aerial photos.
(a)Floating Vegetation (c)Fd	White to pale pink color Smooth texture	This covertype consists primarily of duckweed, floating algae and young grasses. This species association is found floating around shorelines, surrounding marsh or spatterdock islands, and in open waters.
(d)Floating Vegetation (c)Fs	Light pink to deep pink color Smooth to cottony texture	This covertype consists primarily of spatterdock and white water lily. The large islands of this floating vegetation grow in circular disc patterns. They will often be found along channels, surrounding marsh islands or in open water.
(e)Marsh (c)Mc	Grayish red to brownish red color Grainy texture	This covertype consists primarily of a cattail marsh. Three densities of cattails were noticeable on the aerial photography. The uniformity of color and texture was correlated to cattail densities. The brown color which persisted in dense stands was a result of reflectance from the soil mat surface which the cattails are growing on rather than reflectance from the narrow cattail blades.

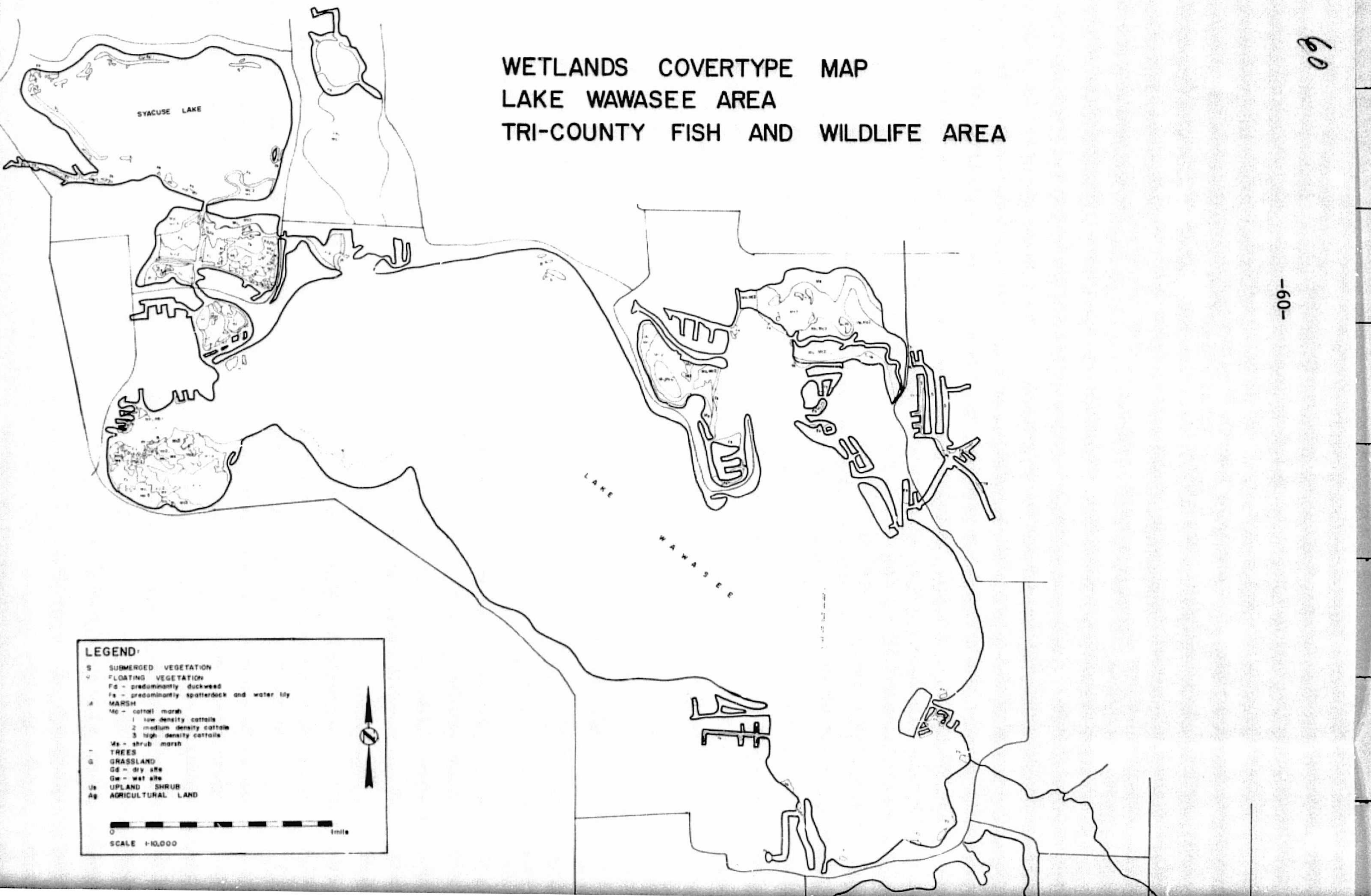
Table 1. (Cont.)

Covertype	Photographic Features	Ecological Description
(b)Marsh (c)Ms	Bright red color Grainy texture	This covertype consists primarily of low shrubs and some grasses. The principal component of this covertype is swamp loosestrife, but other broadleaf shrubs are also present. The covertype is often found dispersed throughout the cattail marsh. However, small homogeneous stands of shrubs, and loosestrife are found within the cattails and apart from the cattails.
Trees T	Bright red color Billowy texture Easily discernible because of higher relief	This covertype consists primarily of mature, fully leafed out deciduous trees of farily uniform high density.
Grassland Gw	Red to pink color Smooth texture	This covertype consists primarily of wet meadows. The grassland often boarders on lakes or marsh land.
Grassland Gd	Red to pink color Smooth texture	This covertype consists primarily of dry meadows not associated with agricultural land.
Upland Shrubs Us	Bright red color Billowy texture	This covertype consists primarily of low bushes and shrubs existing on the well drained upland areas around the Tri-County Fish and Wildlife Area.
Agricultural Land Ag	Variety of colors including red, brown, green and white Smooth texture	This covertype consists primarily of areas which are devoted to farming activity. The field patterns are noticeable on the aerial photography. The various colors correspond to fields of various crops, bare soil or pasture land. The individual fields were not delineated on the covertype map.

Caption for Figure 4. (Foldout)

Wetlands covertype map of the Lake Wawasee and Tri-County Fish and Wildlife Area. The map was developed from interpretation of large scale color infrared photography.

WETLANDS COVERTYPE MAP
LAKE WAWASEE AREA
TRI-COUNTY FISH AND WILDLIFE AREA



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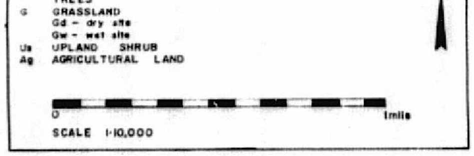
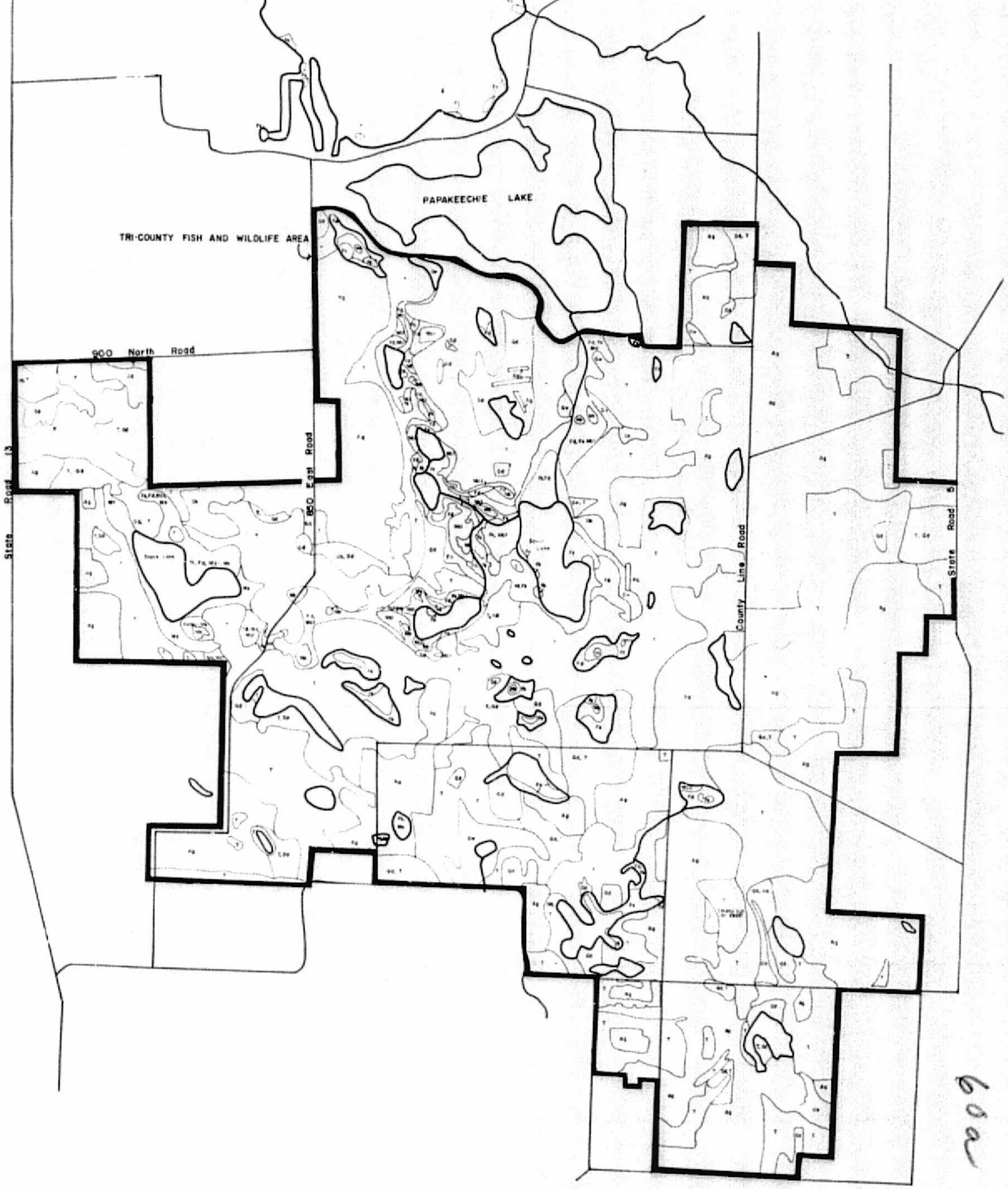


Figure 4.



FOLDOUT FRAME 2

60a

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2. MEYER, M. P. 1975. 35mm aerial photography applications to wildlife population and habitat analyses. Proceedings, Canadian Workshop on Remote Sensing of Wildlife. pp. 31-44.

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FORESTRY DEMONSTRATION PROJECT

INTRODUCTION

For the past year and a half we have been working on a project mapping forest and land resources on the Brownstown Ranger District of the Wayne-Hoosier National Forest. Progress to date is defined in the project status matrix (Figure 1). Advancement to the application or implementation of the classification results into the Forest Services planning cycle has been slow.

Part of our difficulty with this project has been a reduction in graduate staff and difficulty in creating a computer compatible ancillary data set. The graduate student most heavily involved with the analysis and ultimate application of the results left for other employment. We have not yet suitably replaced him. The user (Forest Service) has expressed an interest in obtaining their results on a township and ownership basis. The use of ancillary data in analysis has been highly touted. Unfortunately, there is much room for improvement in the area of creating the necessary data sets to use in the analysis sequence.

These problems have been ironed out. The appropriate steps are being taken to get the project back on track.

PLANNED ACTIVITIES

Before the user is willing to commit himself to apply the computer classification in a decision process, he must have confidence in the results. The next logical phase is twofold: first, evaluation of results and second, manipulation of the data set, which now includes ancillary data, to demonstrate potential application.

A preliminary, cursory evaluation of one township indicated that the classification was not as good as we originally anticipated. However, the problems which we encountered were all attributable to either the data set or the test site. We feel that with a minimum effort we can alleviate these problems and considerably improve the classification. Once these refinements have been completed, we will utilize forest service photography and compartment management information to evaluate the results.

Since the ancillary information (ownership and township boundaries) is now in a computer-compatible format, classification results will be output with this information included. Basically, we will attempt to identify the output products most compatible to the users' needs.

PROJECT STATUS MATRIX

WAYNE-HOOSIER NATIONAL FOREST STUDY

Demonstrations	Current Status: Feasible	Important to User	User Defined Objective	Analysis Phase	Evaluation Phase	Application Phase	Application
Timber - Cover type maps - Density class maps - Slope Aspect maps - Change detection	X	X	X	X	X		Decisions will be made regarding timber production through improved estimates of productivity. Information will also allow better allocation of resources for timber production activities.
Fire - Type maps - Slope Aspect maps - Fire hazard maps - Change detection	X	X	X				Information in these areas will be used to make decisions regarding the size and deployment of fire crews, based on the location of hazardous fire areas.
Wildlife - Cover type maps	X	X	X				This information will be useful in determining habitat diversity and will allow for decisions concerning location [illegible] wildlife openings and waterholes.
Planning - Type maps - Data base - Watershed overlays	X	X	X	X	X		General information as above will help in settling tentative output targets for the forest plan. Watershed information will be useful in locating and protecting impoundments and wetlands.
Land Acquisition	X	X	X	X			General land use maps will be helpful in assessing where parcels of land are and their suitability for acquisition.

Figure 1. Project Status.

COASTAL ZONE MANAGEMENT PROJECT

INTRODUCTION

During the previous reporting period Phase I of the Indiana Coastal Zone Mapping Project was described. In review, Phase I involved using Landsat data to map the forest resources within the 150,000 hectare (375,000 acre) Coastal Zone Management Area in northern Indiana. Figure 1 is a cal-comp classification map which Department of Natural Resources personnel have overlaid on a 1:250,000 scale base map of the area. In addition to the map acreage estimates were provided for four spectral classes of material that was defined as forest. Table 1 gives the area of forest, grouped into three classes by acreage and percent total area.

APPLICATION

The primary purpose of this mapping effort was to provide the Division of Forestry, within the Indiana Department of Natural Resources (IDNR), baseline information regarding the extent and distribution of forest resources in the coastal zone. Information to this degree of specificity was not available elsewhere.

As previously reported, maps and acreage tables were given to IDNR personnel in early May. This material was used in selecting locations for field collection sites. Field data was collected during the summer by two college students working for IDNR. During the nine weeks which they worked, the students were able to collect data about the forest resources for the entire area. Without the computer maps supplied by LARS this accomplishment would have not been possible. Field sample locations were selected and marked on computer printouts showing only a breakdown of the forest classes. Homogeneous areas of approximately ten acres (nine pixels) were selected as candidate field sites. The computer maps, at a scale of 1:24,000 were aligned with USGS quadrangle maps by a point-to-point visual process done over a light table. The process was accomplished by lining up vegetation blocks on the map with the computer symbols.

Candidate tracts (field sample locations) were outlined on the quadrangle maps by placing a sheet of carbon paper between the computer printout and the map. Tracts were then outlined on the printouts. The carbon impression on the quadrangle maps were numbered and coded as one of the four computer classes.

Data collection consisted of random prism points (variable plot radius) located within the identified tract. Field data was sent to the main forestry office in Indianapolis where it was encoded and run through a computer program which estimated various timber stand factors cush as board foot volume, basal area per acre, etc.

In total 291 tracts containing 4731 acres were visited. This would roughly translate to a 1.2 percent sample of the entire coastal zone area or approximately a 5 percent sample of the forest area.

Based on the field results 82 percent of the tracts were correctly classified as either forest or non-commercial forest. Of the remaining 18 percent, the largest misclassification error occurred in suburban areas containing

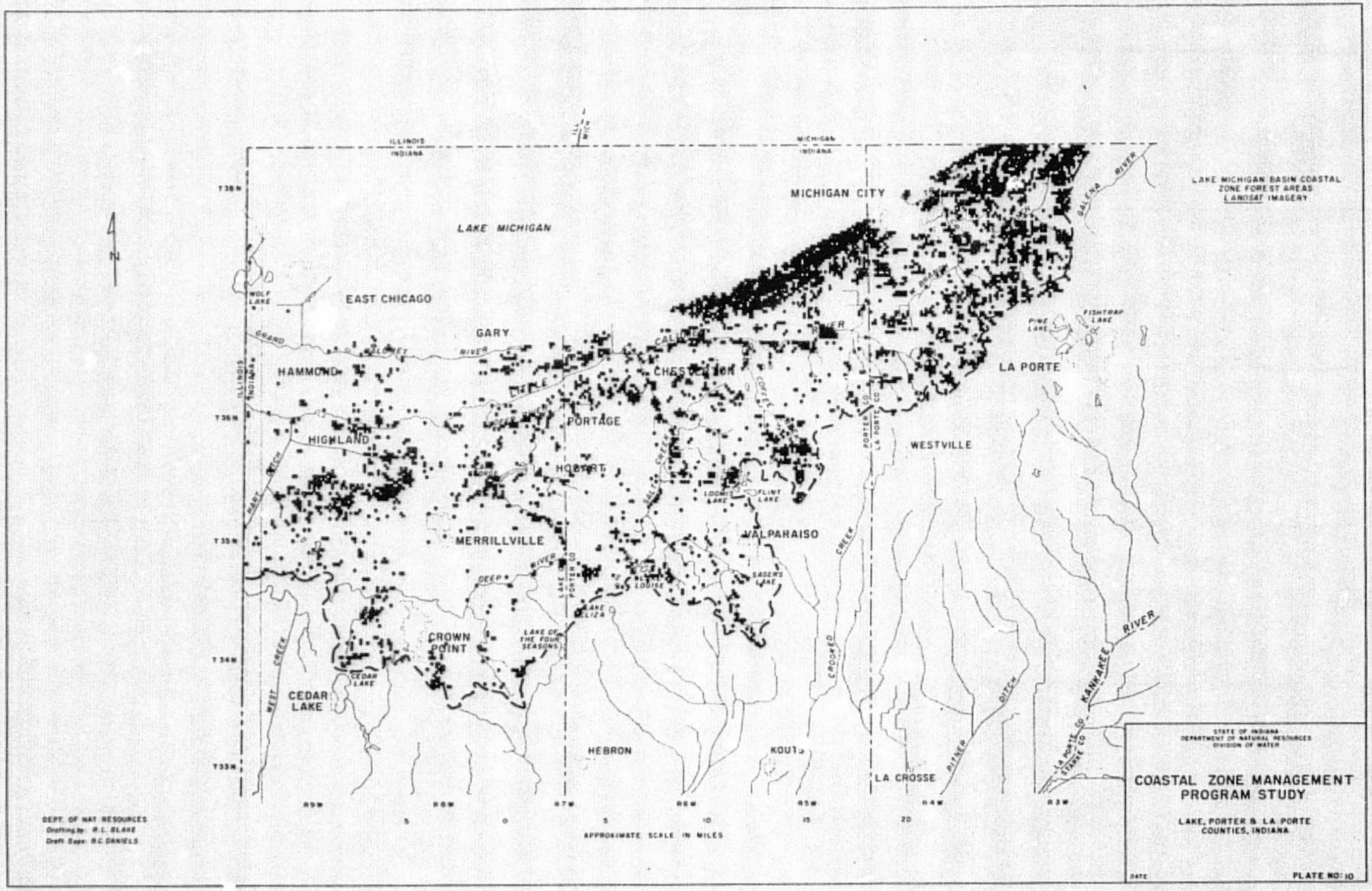

Figure 1. Cal-comp classification map of forest in the Coastal Zone Management Area. Map was prepared from classification of Landsat MSS data.

Table 1. Distribution of forest cover types within the Coastal Zone.*

Forest Type	Acreage	Percent Area
Upland Forest	23,570	6.1
Bottomland Forest	22,887	5.8
Lowland Forest	26,059	6.7
Totals	72,516	18.6

*From Table F-1 Indiana Coastal Zone Plan.

many large old growth trees. This error was due to inadequate definition of that class. Retraining and refinement of the classification should alleviate this type of error.

FUTURE ACTIVITY

Phase I of this study is nearly complete. The only tasks remaining involve an analysis of the field results and refinement of the classification. Phase II will involve defining a more intensive forest inventory based on the new classification. The procedure will involve selection of photo-plots and ground plots and their measurement. The purpose of this inventory is twofold:

1. To identify commercial timber supplied in the coastal zone and
2. To identify areas unique to the coastal zone that require special management.

ACCOMPLISHMENTS

This task has generated a few accomplishments that are worthwhile to note.

- Computer-analyzed Landsat data has provided information to resource managers that would otherwise have been unavailable from any other source in the allotted time.
- Two people each working nine weeks (18-man weeks total) were able to characterize the forest resource in the 400,000 acre management block. Their evaluation and field sampling locations were selected from computer-classified Landsat data. Without the computer input the task would have been impossible to complete in the allotted time.
- The IDNR, Division of Forestry, is seriously considering the use of Landsat data and computer-assisted analysis as a approach to other inventories.